Popular Astronomy.

Vol. XIX No. 1. JANUARY, 1911. Whole No. 181

THE MEASUREMENT OF THE LIGHT OF STARS WITH A SELENIUM PHOTOMETER, WITH AN APPLICATION TO THE VARIATIONS OF ALGOL.

JOEL STEBBINS.

At the request of the Editor, the writer will give to the readers of POPULAR ASTRONOMY the main portions of a paper on selenium photometry, which was published in the *Astrophysical Journal* for October, 1910.

About four years ago I became interested in the possible application of selenium to astronomical photometry, and with Dr. F. C. Brown I began to experiment on selenium cells with the hope of using them for accurate measures of the light of stars. The idea is an attractive one; the proposed method being to expose a selenium surface to the light of a star, focused by a large lens, and to note the change of resistance by means of a galvanometer: the brighter the star, the larger the galvanometer-deflection. In theory this is very simple, but at the outset we met some of the difficulties which confront everyone who tries to work with selenium. Other agencies than light affect the resistance, and apparently no experimenter has solved, to his own satisfaction, the mysteries of this peculiar element.

After some futile attempts to obtain results from starlight at the focus of a 12-inch refractor, we found that a selenium cell gave large effects when exposed directly to the Moon. This led to a study of the variation of the Moon's light throughout a lunation,* and it was also found that various selenium cells have widely different curves of color-sensibility.† One reason that physicists and electricians have not used these cells in photometry is that selenium is relatively most sensitive to red light, but in certain kinds of astronomical work, such as the study of eclipsing variable stars, it is quite immaterial what part of the spectrum is used.

* *Astrophysical Journal* 26, 326, 1907.

† *Ibid.*, 27, 183, 1908.

During several years of experimenting I have tried the selenium cells of different makers, whose processes are secret, also a number of cells made by Dr. Brown and myself. The best cells known to me are those by Giltay of Delft, Holland. In the form which he uses, two wires were wound in a double spiral about a flat insulator, and the spaces on one face are filled with selenium which is properly treated to make it sensitive. In response to my inquiry, Mr. Giltay has said that his method of sensitizing is indeed a secret, but he adds that it is often a secret even to himself, for after thirty years of experience in making cells he frequently has surprises, and usually of the disagreeable kind.

Fig. 1. shows the sensitive face of a Giltay cell, the terminals being brought out at the back of the case. The area of the sensitive surface is 50 × 26 mm.

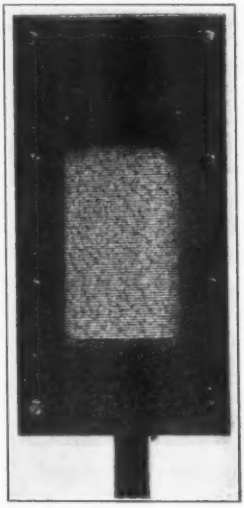


FIGURE 1.
SELENIUM CELL BY GILTAY

In working with faint lights, we found that a small variation in the temperature of a cell gives a greater change of resistance than is produced by the light of the brightest stars. Numerous attempts were made to maintain a constant temperature with thermostats, but although some improvement was noted, the irregularities remained almost hopelessly large. One of the fundamental obstacles is the heating effect of the current which is necessarily passed through the selenium to measure the resistance. It is unnecessary to enumerate the various experiments which were made, but after a long time I learned that there are three simple precautions necessary to insure success, and they are given in what seems to be the relative order of importance:

1. The selenium should be kept at a uniform, low temperature, 0° C., or lower.
2. The current should pass continually through the selenium.
3. Exposures to light should be short, say 10 seconds, with longer intervals for recovery.

Such success as I have secured has been through the observance of these simple precepts, and although other experiment-

ers have not formulated such rules, I have been quite unable to do anything in measuring starlight without adhering to them. In discussing the reasons for these precautions, it is not possible to give numerical results which are applicable to different cells, but the general principals seem to hold whereever faint lights are to be measured.

First, the effect of low temperature is best illustrated by an example. A cell of about 1,000,000 ohms resistance at 20° C. increases to 3,000,000 ohms at 0° C. It is found that small variations in temperature produce relatively much less effect upon the higher resistance, and, in terms of galvanometer-deflections, the irregularities are in the ratio of about 50 to 1 in favor of the low temperature. Also, the light-action is about twice as great at 0° as at 20°, and we have the rather astonishing result that it is possible to increase the effective sensibility of a cell 100 fold merely by reducing its temperature. In practice it is not difficult to surround a cell with an ice-pack, but moisture must be kept from the cell and from the insulation of the connecting wires.

Second, the current which passes through the selenium should not be interrupted. If an E. M. F. of 6 volts be applied to a cell of 3,000,000 ohms, the resistance decreases slowly, until at the end of half an hour a steady condition is reached where the resistance is about 10 percent less than at the start. This change is presumably due to the heating of the current, which is enough to account for the decrease. In terms of galvanometer-deflections, this heating effect is of the order of 100 times the light effect from a bright star, and therefore the cell should not be disturbed by breaking the circuit.

Third, as is well known, selenium requires some time for recovery from light-action, and it is found that if a cell be exposed for 10 seconds to starlight, it is best to wait about 1 minute to insure recovery and allow the cell to regain its original sensibility.

Other precautions are the same as must be taken in any work where high resistances and a sensitive galvanometer are used. Good insulation is essential and the connecting wires must be shielded from the effect of static charges, which are especially large in cold weather.

As the character of the galvanometer used is of considerable importance, I shall give the constants of the one I have at present, which was made by the Weston Electrical Instrument Co. It is of the d'Arsonval type, with flat mirror 8 mm. in

diameter, and is used with a view telescope magnifying 25 times, and a millimeter scale placed at from 2 to 4 meters distance. The resistance is 512 ohms. The period of complete free swing is 5.0 seconds, and when connected in circuit the instrument is practically dead beat. The "figure of merit," or current required to produce 1 mm. deflection at 1 meter scale-distance, is 2.4×10^{-10} amperes, but because of the excellence of the optical system a current of 5×10^{-12} amperes can be detected with certainty. Although this sensibility is not the highest possible in a galvanometer, it is the best I have ever seen in one of the d'Arsonval type, and there is the great advantage that the instrument is practically unaffected by external conditions.

In the arrangement for measuring starlight the selenium cell is connected as one arm of a Wheatstone bridge. Current is supplied by a few dry cells which are ample for the purpose. The resistances of the selenium cell, galvanometer and battery being fixed, the other arms of the bridge should be chosen to give the maximum current through the galvanometer for a small change in the resistance of the selenium. Convenient formulae for the best arrangement have been derived by Heaviside;* but as megohm resistance boxes are somewhat expensive, I have found that with resistance of 10,000 ohms and less it is possible to obtain fully three-fourths of the computed maximum sensibility. Precaution must be taken that the resistances are so arranged that the galvanometer is not damped excessively, in order that full deflection may be secured.

Fig. 2. shows the ice chamber containing a cell, attached to our 12-inch telescope. In warm weather the ice is renewed every day, but in winter the end of the telescope is wrapped up in a blanket, and may not be disturbed for a month at a time. Exposures to starlight are made by opening a small shutter which is operated by hand, the observer listening to the beats of a chronometer. In Fig. 3 are shown the galvanometer, scale and resistance boxes which are located in a room some distance from the dome, the two wires leading from the telescope being easily carried to where it is convenient to mount the galvanometer. In practice we always have two observers, one to point the telescope and make the exposures, while the other reads the galvanometer and records

* *Philosophical Magazine*, 45, 114, 1873.

the measures. Contrary to astronomical custom, the recorder is the real observer in this work, and the assistant is stationed at the telescope. In fact, it often happens that the man at the galvanometer can tell that the sky is growing less transparent, before the observer in the dome can ascertain the same by direct inspection.

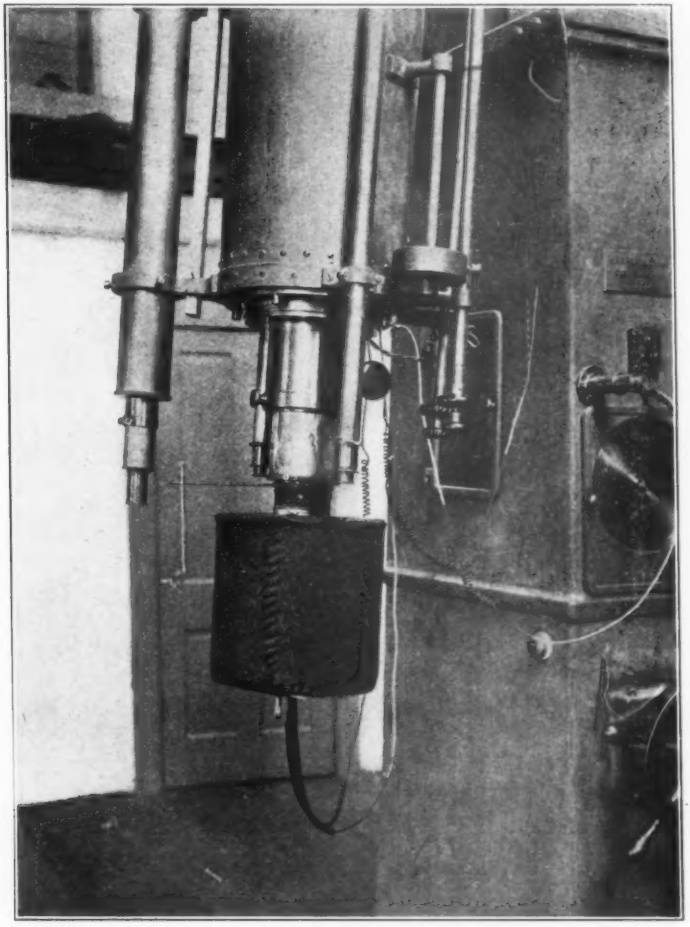


FIG. 2. SELENIUM CELL IN ICE PACK ATTACHED TO 12-INCH REFRACTOR.

This brief outline of the method of using selenium in photometry will perhaps indicate the general way in which the

observations are made, but the procedure will be better illustrated by giving the actual figures and results derived in an exhaustive study of a variable star.

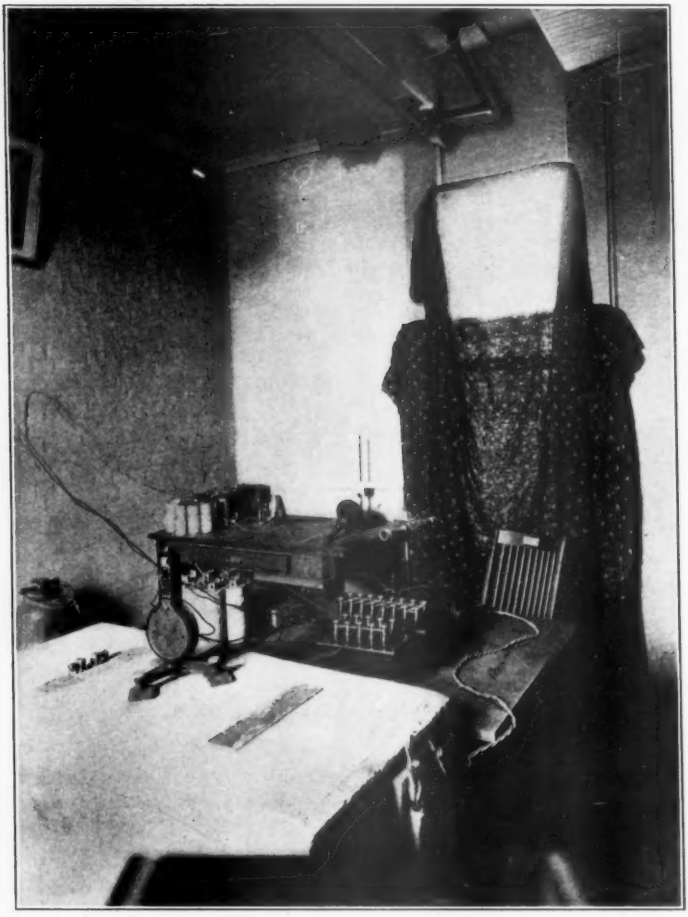


FIG. 3. GALVANOMETER AND ACCESSORIES FOR SELENIUM PHOTOMETER.

APPLICATION TO THE LIGHT-VARIATIONS OF ALGOL.

As soon as the experiments were begun with selenium, I had it in mind as one of the problems to take up, when it became possible to measure starlight with accuracy, to investigate the light-curve of *Algol*, especially for a secondary minimum, which

if present, would give us valuable information concerning the companion. The history of the investigations of *Algol* is so well known, even to the general reader, that it is superfluous to mention the names of the astronomers who have contributed to our knowledge of this star. In fact, we may say that if any star in the whole sky has been subjected to an exhaustive study, *Algol* is that one. For this very reason, however, it seemed advisable to try the selenium photometer, for this star would furnish an excellent test of the improvement of our work over visual methods.

It was found on trial that with good conditions a 10-second exposure of our best selenium cell to *Algol* at maximum light gave a scale deflection of 8.0mm. The probable error of a single deflection was of the order of 0.16mm, or about 2 per cent, and as this was a better accordance than can be secured in visual work, I felt ready to adopt a program for observing this star during several months. In illustration of the accuracy which was insisted upon, it may be said that when the cell happened to become so irregular that the probable error of one deflection became higher than 5 per cent, observations were not undertaken.

On account of the atmospheric absorption, there is, of course, no method of measuring the light of a star, which does not include observations of one or more comparison stars. On consideration, I decided to use α *Persei* and δ *Persei*. After making this decision, I found that these same stars had been chosen by Müller,* whose determination of the light-curve is perhaps the best that has ever been made visually. The normal plan with selenium was to make 4 exposures on α *Persei*, then 8 on *Algol*, and finally 4 on α *Persei*. Such a series of 8 readings on each star will be called a set. When *Algol* was near minimum, both α and δ were used, and a set of readings usually consisted of 4 on α, 4 on δ, 8 on *Algol*, 4 on δ and 4 on α. When only two stars were observed, the 16 deflections of a set were secured in about 20 minutes, including the time for moving the dome and telescope. Ordinarily it was considered that 4 to 6 sets of measures were sufficient for one night, but when the phase of *Algol* was near principal minimum, or the supposed secondary minimum, the observations were continued all night, or as long as conditions would permit. The method of observation and reduction is best illustrated by an actual sample, and the following represents a typical page of the notebook.

* *Astronomische Nachrichten*, 156, 178, 1901.

FRIDAY, JANUARY 7, 1910.

Observers, J. S. and P. F. W.
Cell, Giltay No. 93, area 18×26 mm.
Extra-focal star image, 7 mm. diameter.
Ratio arms, 10,000 and 10 ohms.
Resistance of cell, 5,000,000 ohms.
Dome temperature, — 5° C.
Galvanometer, Weston.
Scale-distance, 2.3 meters.
Battery, 7 Edison cells, 6 volts.
Exposures, 10 seconds.
Sky, fair; absorption factor, 2.
Wind, south.
Watch ΔT, + 4 seconds.

Time	Readings	Deflections
	α *Persei*	mm.
8h 18m	280.0–87.3	7.3
19	281.7–88.9	7.2
20	282.9–90.2	7.3
21	284.4–91.6	7.2
		7.25
	Algol	
8h 24m	278.0–84.7	6.7
25	279.9–86.4	6.5
26	281.9–88.2	6.3
27	283.3–89 7	6.4
28	284.3–90.4	6.1
29	285.2–91.3	6.1
30	285.7–92.1	6.4
31	286.8–93.1	6.3
		6.35
	α *Persei*	
8h 34m	282.1–90.0	7.9
35	285.6–93.3	7.7
36	288 3–96.0	7.7
38	290.2–97.8	7.6
		7·72
		7.25
		Mean 7.48

REDUCTION

Mean time	8h 28m	
Sidereal time	3 42	
Star	α*Persei*	*Algol*
Deflection, D	7.48	6.35
Drift	− 0.02	—0.02
Corrected D	7.46	6.33
Log. D	0.873	0 801
Log. ratio	0.072	
Difference of magnitude	0.18	
Absorption	0.00	
Corrected difference	0.18	

RESULTS ON JANUARY 7, 1910.

Time	Difference of Magnitude	Residual	Time	Difference of Magnitude	Residual
$8^h\ 28^m$	0.18	0.00	$9^h\ 26^m$	0.16	−0.02
8 47	0.17	−0.01	10 00	0 22	+0.04
9 07	0.20	+0.02	10 19	0.16	−0.02
Means 8 47	0.18		9 55	0.18	±0.02

Other experiments have shown that for faint sources the galvanometer deflections are sensibly proportional to the light intensity, and therefore the ratio of the deflections gives at once the difference of magnitude of the two stars. The main corrections which need to be applied are due to progressive drift of the galvanometer and differential atmospheric absorption. At the beginning of each night's work, a series of readings was taken to determine the rate of change of the galvanometer zero, due to small temperature-variation in the selenium cell, this being repeated about once an hour, and the drift was then interpolated for the times of the measures of the stars. Near minimum, the difference in the deflections between *Algol* and α *Persei* was so large that the drift was of much consequence, and measures of δ *Persei* were utilized for the determination of drift. From the observations on a number of nights, the difference of magnitude between α and δ *Persei* was found to be 1.10 magnitudes, and this value was used for computing the drift.

The correction for atmospheric absorption was based upon the Potsdam tables by Müller.* A table of the correction was computed for *Algol*, α and δ *Persei* for each half hour of sidereal time, and the interpolated value from this table was multiplied by the factor, 1.0, 1.5, or 2.0, depending upon my judgment of the transparency of the sky. This may seem like a crude method, but in four-fifths of the cases the correction was either 0.00 or 0.01 magnitude. When *Algol* became relatively low in the west, additional observations for the absorption-factor were taken on β *Andromedae*, but there were only 3 sets of measures where the correction was greater than 0.04 magnitude.

Near the time of full Moon, the bright background of the sky gives an appreciable deflection of the galvanometer; but where necessary this effect was carefully determined and allowed for in the reductions.

* *Die Photometrie der Gestirne*, Leipzig, 1897, p. 515.

Observations of *Algol* were begun in September 1909, and continued until March 1910, a total number of 269 sets of measures being secured. As it required from twenty minutes to half an hour to finish each set, some idea will be gained of the effort which was made to secure the best possible light-curve. The work extended over two to seven hours on each of 48 nights, and this does not include the numerous occasions when clouds interrupted the observations. Whatever merit there is in the selenium photometer, it has as yet no claim to speed, though if we desired results where an occasional error of 0.1 or 0.2 magnitude could be admitted, stars might be observed at the rate of one per minute or faster.

The detailed results of the measures are in my original paper, and need not be repeated here. It was found that the minimum of *Algol* came 1h 16m earlier than the time predicted in the ephemeris based upon Chandler's latest elements.

The observations were arranged according to phase, and each successive 3 or more sets were combined, the normal magnitudes containing sets as follows:

Near principal minimum..... 3 sets
Near secondary minimum..... 6 sets
Between minima ..... 9 or more sets

It was afterward found that the duration of the eclipsing phase is less than 10 hours, and the first and last normals near principal minimum include 6 sets of measures. In Table II are listed the normal magnitudes, where the difference of magnitude is in the sense: magnitude of *Algol* minus magnitude of α Persei. The third column gives the residuals formed by a comparison with the final light curve, computed from the elements of the system of *Algol* which I have derived.

Except near principal minimum, the accordance of the observations justifies carrying the normal magnitudes to the third decimal, and it will be seen that the accuracy obtainable with the selenium photometer, for bright stars at least, is greater than has been attained in any visual or photographic method.

From the residuals in Table II we have

Probable error of a normal magnitude near principal minimum $=\pm 0.023$ mag.
Probable error of a normal magnitude near secondary or between minima $=\pm 0.006$ mag.

One peculiarity of the selenium photometer is that the errors, expressed in magnitudes, increase for faint stars, but in light-units the accordance is practically the same for any intensity. In visual observations, the residuals in magnitude are about

TABLE II

NORMAL MAGNITUDES

NEAR PRINCIPAL MINIMUM			NEAR SECONDARY MINIMUM		
Phase	Difference of Magnitude	O.—C.	Phase	Difference of Magnitude	O.—C.
−5h 18m	0.18	+0.01	31h 52m	0.150	0.000
−4 22	0.20	−0.02	32 30	0.147	−0.014
−3 54	0.28	0.00	33 00	0.182	+0.012
−2 41	0 55	0.00	33 49	0.172	−0.011
−1 39	0.88	−0.01	34 24	0.195	+0.007
−1 08	1.09	0.00	34 54	0.193	+0.005
−0 41	1.21	−0.05	35 24	0.182	−0.002
−0 08	1.35	−0.02	36 07	0.172	−0.003
+0 25	1.37	+0.04	36 51	0.160	−0.003
+0 48	1.15	−0 06	37 27	0 148	−0.004
+1 13	1.08	+0.02	37 59	0.142	0.000
+1 34	0.97	+0.04	38 37	0.137	+0.004
+2 03	0.69	−0.06	39 38	0.122	−0.006
+2 34	0.64	+0.05			
+2 55	0.42	−0.07			
+3 16	0.42	+0.02			
+3 50	0.30	+0.01			
+4 14	0.23	0.00			
+4 42	0.19	+0.01			
+6 14	0.17	0.00			

BETWEEN MINIMA		
9h 58m	0.163	−0.002
12 10	0.153	−0,007
14 01	0.170	+0.012
19 33	0.143	−0.002
24 25	0.130	−0.005
27 01	0.138	+0.006
42 41	0.140	+0.008
46 06	0.123	−0.017
50 26	0.147	−0.001
55 40	0.168	+0.008
59 49	0.168	0.000

the same over a wide range of brightness. Where a variable star has a range of 1 magnitude and eye observations are expressed in light units, the probable error near minimum is only two-fifths that at maximum, and according to the usual method the weights should be assigned as 6 to 1. So far as I know, no computer has taken this fact into account, although there have been many elaborate calculations of the elements of different variable stars. In this connection, I may say that I am quite unable to see the justification for publishing the elements of a system like that of *Algol* to 4 or even 5 significant figures, when the original data are often not exact to 2 places, and when even the first figure of some of the results may be in error.

The normal magnitudes of Table II are shown graphically in

Fig. 4. The first peculiarity of the light-curve which will attract those familiar with *Algol* is the existence of a secondary minimum. This has been sought for in vain by visua observers, though in my opinion if *Algol* were not so bright, the variation of 0.06 magnitude might have been detected. Of perhaps equal interest is the continuous variation in the light between minima, showing this star to be a distant relative of

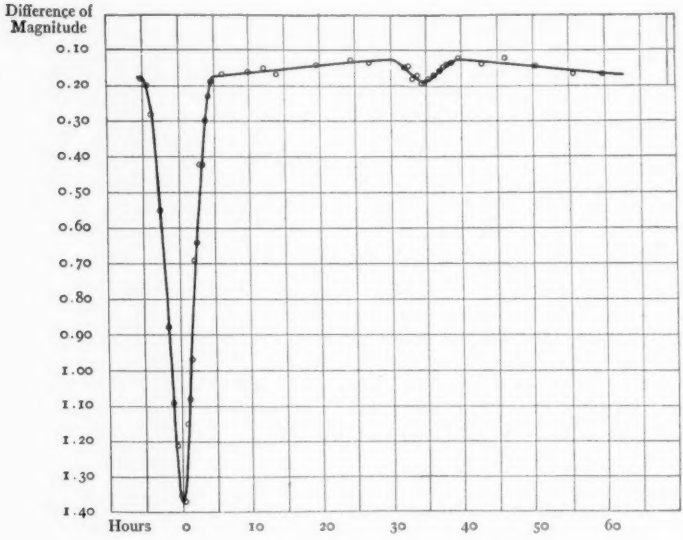


FIG. 4. THE LIGHT CURVE OF ALGOL.

β Lyræ, though the maximum brilliancy does not seem to occur midway between minima, the curve being highest just before and after secondary minimum. The fact that a smooth symmetrical light-curve fits in with the observations is perhaps sufficient reason for considering the continuous variation to be real.

In the second part of this paper will follow a discussion of the theory of the *Algol* system on the basis of these photometric observations.

(To be continued.)

THE HARVEST MOON.

ARTHUR K. BARTLETT

Near the time of the autumnal equinox, the Moon, at her "full," rises shortly after sunset for several evenings in succession, which circumstance gives rise to a series of brilliant moonlight nights, and the Moon being above the horizon until late in the morning, presents a charming appearance besides prolonging the light which is so beneficial to the husbandman at this season of the year. The full Moon that occurs nearest to September 22 has long been known as the "Harvest Moon" on account of the peculiar advantages derived from moonlight during the time of harvest in England, and its yearly return is always celebrated as a festival among the peasantry. The beautiful appearance of the Harvest Moon has from time immemorial attracted the attention of the poets, many of whom have made it the subject of their song, and Henry Kirke White, who died at the age of 21 years, wrote some lines regarding the phenomenon which have become famous.

The circumstance of this Moon rising for several nights in succession at nearly the same hour, immediately after sunset, has given it an importance in the estimation of farmers, but it is not less remarkable for its singular and splendid beauty, as no other Moon during the year can compare with it in brilliancy and magnificence. At its rising it has a character so peculiarly its own, that the more a person is accustomed to expect and to observe it, the more it strikes him with astonishment. We should advise everyone who can go out into the country away from city lights, to make a practice of watching for its rising. The warmth and dryness of the Earth, the clearness and balmy serenity of the atmosphere at that season, the sounds of voices borne from distant fields, the freshness which comes from the evening, combine to make the twilight walk delightful; and scarcely has the Sun departed in the west, when the Moon in the east rises from beyond some solitary hill, over a broad lake, or from behind the dark rich foliage of the trees, and sails up into the still and transparent air in the full magnificence of a world. It appears not as is common, a fair but flat disk on the face of the sky, but we behold it suspended in the crystal air in all its greatness and rotundity; we perceive the distance beyond it as sensibly as that before it; and its

apparent size is surprising to us as it rises above the horizon. The planets and stars lose their lustre when the rounded orb of the September full Moon looms above the horizon to the eastward as the Sun sinks below that to the westward, and as she rises slowly toward the zenith her light dims that of the brightest stars in the firmament. The soft, mysterious rays of the moonlight gradually steal about us and flood the sleeping Earth with their silvery light. It seems at this season to have almost a wizard's power, casting a fairy glamour everywhere, and covering the landscape with wierd shadows. Wherever the moonbeams rest they paint pictures of ineffable loveliness that no mortal pencil can ever reproduce. An Arab poet at Haroun's court said the new Moon was a "horseshoe wrought of God," and so the world over poets in the azure vastness of the infinite have placed the Moon as the focus point of the loveliest fancies that have come to them.

The annual appearance of the Harvest Moon was noticed and anxiously awaited by the husbandmen long before they could interpret the phenomenon, from the fact that it enabled them to lengthen the days work during the haste of gathering the autumnal crops, as the moonlight evenings continued for an unusually long time. The Moon travels towards the east and therefore comes to the meridian about 51 minutes later each succeeding night, and if the interval between her rising and her arriving to the south were always the same, she would rise 51 minutes later each evening on the average. As the solar day lengthens fastest at spring when the Sun crosses the equator from the south to north, so the time the Moon is above the horizon lengthens most, day by day, when the Moon is crossing the equator from south to north, as she does in September every year.

The full Moon that occurs in October which exhibits in almost the same degree the curious phenomena we have described, is sometimes called the "Hunter's Moon," and it is about equally beautiful and attractive in appearance. It is the name given to the lunation immediately following the "Harvest Moon," and it is so-called, not because it enables the hunter to pursue his game at night, as is generally supposed, but because the crops having been harvested in September, there is nothing to interfere with the sportman's pleasure.

The Harvest Moon is not generally understood by the public, but the true cause has long been known to astronomers and can be very easily explained. It arises from the fact that the

ecliptic, or the Sun's apparent path through the heavens, is variously inclined to the horizon at different seasons of the year. The celestial equator is always at the same angle with horizon, and hence equal portions come above the horizon in equal periods of time. If the Moon moved in the celestial equator, she would rise and set directly in the east and west points of the horizon respectively, and she would rise later each night by a nearly constant interval. But the Moon moves in a path which is constantly inclined to the ecliptic at an angle of about five degrees, though for the present explanation she may be regarded as moving in the ecliptic; and as the ecliptic is inclined to the celestial equator at an angle of 23-1/2 degrees the Moon, in all parts of her orbit, does not rise at equal intervals on each succeeding night.

When the constellation Pisces is in the eastern horizon the ecliptic rises with the least angle. Now, in September, at the autumnal equinox, the Sun being in the constellation Virgo, the Moon at her "full," when opposite to the Sun, is in Pisces and rises at sunset. On the following night, though the Moon has advanced in her orbit about 13 degrees, yet her path being very oblique to the horizon, she will be but little below her position at the same time on the preceding night. She rises, therefore, only a little later, and for several evenings appears in the east at nearly the same hour after sunset.

Though the differences in the time of the Moon's rising are always great when she is in or near the constellation Virgo, and small when she is in or near Pisces—that is, every month—yet we never notice these variations except in autumn. In fact we seldom observe the Moon's rising at all unless it be when she rises near sunset, or in the very early evening. We usually give more attention to the full Moon, and the Moon can be full in or near Pisces, where the difference in the time of her rising is least only when the Sun is in or near Virgo, which cannot occur except in September at the time of the autumnal equinox. In March the conditions are reversed, and the Moon at her "full," rises on successive evenings later than at any other time of the year.

In our latitude, the difference between the hours at which the full Moon rises on succeeding evenings in September, amounts, on the average, to rather more than 20 minutes, or about half an hour less than the mean interval, while in March the average difference is about 1 hour and 20 minutes, the least possible variation in the time of her rising being 10

minutes, and the greatest 1 hour and 30 minutes. Those parts of the ecliptic which rise with the smallest angle set with the greatest, and those which rise with the greatest set with the least, so that, while in September the full Moon rises at nearly the same hour on successive evenings, the time of setting varies considerably, owing to the large angle of the ecliptic with the western horizon. The phenomenon of the "Harvest Moon" is much more striking in Northern Europe and in Canada than in the United States; and in very high latitudes the Moon, when it has its greatest possible declination, becomes circumpolar for a certain time each month, and remains visible without setting at all (like the "midnight Sun") for a greater or less number of days, according to the latitude of the observer.

The Moon's nodes are those points in her orbit at which she crosses the Earth's orbit or ecliptic. The place where she passes the ecliptic in moving north is called her ascending node, while the opposite point, or the place where she intersects the ecliptic in moving south, is termed her descending node. These nodes do not remain stationary, but move backward on the ecliptic from east to west, completing an entire revolution in about 18-6/10 years. When the Moon's ascending node is in or near the constellation Pisces or the vernal equinox, the interval between successive risings will be yet more shortened, and the harvest Moons are then most beneficial to us, but if her descending node is situated in or near Pisces the effects are diminished and the phenomena are least beneficial to us.

The husbandman of old believed that the so-called "Harvest Moon" was a divine interposition to prolong the day and thus aid them, but science has shown that the phenomenon is simply the result of natural law. The name so devoutly given is, however, still lovingly cherished, and as long as the solar system preserves its present relations, the return of the "Harvest Moon" will each year commemorate the simple faith of the first observers of this crowning beauty of our September nights.

Battle Creek, Michigan.

THE ORBIT OF HOLDEN 60, B. G. C. 12696.

PHILIP FOX

As the remeasurement of all the double stars discovered by Holden at the Washburn Observatory has been the backbone of my double star observing program, this star, Holden 60, naturally came to my attention. The early measures had indicated rapid relative motion and when these were platted with my recent observations it seemed that enough of an arc had been described to permit the derivation of an orbit which might serve as a first approximation.

The complete list of measures upon which this orbit is based is given below.

		°	″		n
1	1881.71	124.1	0.62	β	3
2	1888.17	105.5	0.49	Com	3
3	1893.13	91.1	0.25	Com	1
4	1902.62	345.5	0.45	β	1
5	1905.68	331.4	0.28	β	2
6	1906.72	326.7	0.23	β	1
7	1907.69	316.5	9.31	β	1
8	1908.03	117.9	0.65	H.F.	1
9	1909.22	306.3	0.26	Fox	2

1. Pub. Washburn O. 1, 89. 2. Sid. Mess. 9, 79. In Washburn O. 6, 129, this is given 105°.0 0″.54. 3. Pub. Washburn O. 10, 76. 4, 5, 6 B.G.C. 7. A. N. 4302. 8. M. N. 69, 603. The angle should probably be reversed on the measure but even then it seems discordant. 9. The two nights measures are both with the 40-inch refractor of the Yerkes Observatory as follows:

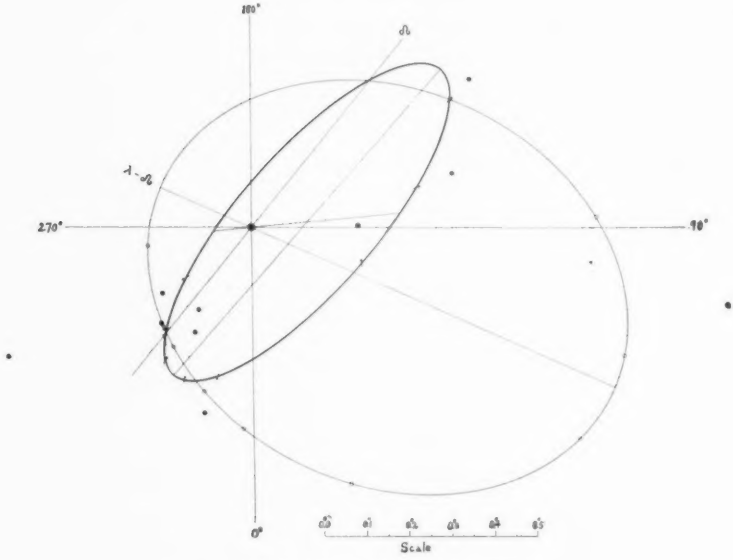
1908.884	307.0	0.26
1909.559	305.6	0.26 cleanly resolved
1909.22	306.3	0.26

The following elements have been derived by the graphical method described by Burnham in POPULAR ASTRONOMY 1, 349, 1894.

$$
\begin{aligned}
P &= 40.0 \text{ years} \\
e &= 0.60 \\
a &= 0''.581 \\
T &= 1870.0 \\
i &= 73°.8 \\
\Omega &= 141°.3 \\
\lambda &= 255°.1
\end{aligned}
$$

APPARENT ORBIT

Length of major axis	= 0″.956
Length of minor axis	= 0″.310
Angle of major axis	= 138°.6
Angle of periastron	= 275°.6
Distance of star from center	= 0″.130



THE ORBIT OF HOLDEN 60.

The true and apparent orbits are shown in the accompanying figure. The observed positions are represented by dots. Further, taking the elements above I have computed the positions for the dates of observation and these are given on the true orbit as circles and also projected on the apparent orbit, where they appear as arrows directed toward the observed positions. With what degree of accuracy the apparent ellipse represents the observations and how the observed and computed positions differ may be seen at a glance.

This orbit is probably subject to considerable uncertainty but it will at least call attention to the interesting character of this star.

Dearborn Observatory, Nov. 22, 1910.

THE UNIVERSE A MECHANISM.

JOHN CANDEE DEAN

Organic progress consists in a change from the homogeneous to the heterogeneous, and the law of organic progress is the law of all progress. It makes no difference whether we examine into the development of society, government, commerce, language, literature, art or the sidereal heavens, the same evolution of the simple into the complex through successive modifications will be found. Hence, may we not conclude that all existing things, from the electron up, are the result of evolution?

The idea that all forms of organic life came into existence by growth, through the variation of primordial germs, is as old as philosophy. In 1637 Descartes became the founder of modern philosophy by the publication of a volume of scientific essays in which he set forth the claim that the universe, organic and inorganic, is a mechanism and explicable on physical principles. The philosophy of Descartes was physical in all its branches. His theory like the later theories of Kant and Laplace gave a hypothetical explanation of planetary motion on a mechanical basis. For ages the Sun and the planets were themselves believed to be divine personalities; after Greek mythology was overthrown, angels were supposed to carry the planets around in their orbits. Descartes dismissed these "divine movers" to whom even Copernicus and Kepler had assigned the guardianship of planetary motion. Later Newton discovered the law of universal gravitation, and Laplace confirmed the mechanical origin of the fabric of solar system, by giving a mathematical interpretation to the laws of the cosmic mechanism. Descartes' theory of vortices is said to be one of the most ingenious hypotheses which philosophy has devised for explaining gravitation.

The early writings of the severely critical Kant were principally on physical science. When he returned to Königsburg, in 1755 he published a most remarkable work entitled "General History and Theory of the Heavens," in which he launched the hypothesis of the original nebulous condition of the solar system and the evolution of our planetary system from rings separated from the central mass. This work was a bold attempt to treat of the constitution and mechanical origin of the entire fabric of the universe according to Newtonian laws,

and was a keen anticipation of the nebular hypothesis of Laplace. Kant declared that "there can be no science without the mechanism of nature."

His work was published anonymously and at once passed into oblivion. Ninety years later it was resurrected by Alexander Humboldt in the first volume of his "Kosmos", published in 1845. While Kant's work was sleeping in its grave, Laplace independently reached similar conclusions, which he fortified with mathematical demonstrations, published in his masterly "*Exposition du Systeme du Monde*" in 1796. The world has not produced a greater mathematician and astronomer than the man who conceived of the concentration of rotating nebulous matter toward its center of gravity and explained the natural process by which there would be formed a balanced group of planets and satellites revolving around a central Sun The cosmogonies of Kant and Laplace were analogous in that they both furnish a mechanical explanation of the evolution of our solar system from a nebula, and the further conclusion was drawn, that all other systems of the universe were developed from rotating nebulae. Thereafter the conception of modern evolution became irrepressible.

During the Middle Ages, where the natural cause of a phenomenon did not reveal itself, the learned at once assigned to it a supernatural cause. People so reverenced erudition that they could not see that scholarship, to have value, must be knowledge. In order to comprehend natural phenomena and discover natural laws, it was first necessary to divest man of the belief that he was the preordained center and aim of all creation. It required the genius of Descartes, Kant, Newton and Laplace to deliver him from this illusion. It was the astronomer who first revealed to man the simplicity and grandeur of Natural laws, and having wrung from nature some of her secrets, he now coerces her in the name of these laws which she can neither change nor conceal.

The discoveries of the astronomer and physicist have disclosed a universe of beauty, order, rhythm and law, but it must not be assumed that Nature promises eternal progress. The ultimate movement of all evolutionary processes must be in a circle, in which progress and retrogression eventually balance. Progressive evolution must be followed by retrogressive devolution. The Earth is now in that part of the cycle where integration predominates and we have progress; but the cycle will close with a period in which disintegration will predominate and dissolution ensue.

PLATE II.

SPIRAL NEBULA, M. 101 URSA MAJOR.

Photographed with the two foot reflector at Yerkes Observatory.

This nebula was probably formed by partial impact of swiftly moving stars. It will, perhaps in time, develope into a system of planets revolving around a central sun.

It is now generally admitted by the informed that all forms of living organisms, including man, have been evolved from primitive forms of life in which there was no break in the continuity of the process. The orderly processes in life, and the structure of animals and plants have developed by mechanical laws, and these powerful natural forces have for millions of years exercised supreme control over the entire course of organic evolution.

The law of mechanical causality teaches us that every phenomenon has its mechanical cause, and the entire universe, including the mind of man, is ruled by this law. The science of evolution has been carried beyond the planets, beyond the solar system, and into the deepest recesses of the sidereal universe.

The spectroscope shows that the blinking star Algol, alternately advances toward us and recedes from us at a rate of twenty-six miles a second in a period synchronous with that of its variability. The explanation of the changes in its brightness is found in a binary system in which a dark body smaller than Algol revolves around it in an orbit lying edgewise to us, so that at each revolution Algol is partially eclipsed by the dark star. The discovery of a large number of short period variable stars of the Algol type indicates that black stars are very numerous, and Sir Robert Ball expresses the opinion that they outnumber the lucid stars. These black bodies are dead Suns that have lost their heat energy by radiation and are like clocks that have run down.

There is evidence that there is a regenerative influence at work in the creation of new nebulae by the accidental collision of stars. This appears to be Nature's method of preventing the final dissipation of energy which would occur from the gradual cooling of hot bodies and the warming of cool bodies until all matter would be of one temperature. Stellar impact differentiates the temperatures of stars, and thereby prevents all matter from attaining the same thermal level. The mighty machinery of the cosmos is immortal in its workings. Systems are evolved, play their parts on the great stage of the universe, are scattered for a time, only to reappear in new and equally glorious forms. Ceaseless change is the only constant thing in nature. The complete cycle of changes carries matter through all its phases, from the simplicity of matter in the hottest nebula up to the complexity of matter in the planets and in the common Earth.

When a star suddenly blazes forth in a place where none had been observed before, the phenomenon is supposed to be the result of a collision between celestial bodies, which may be either bright stars, black stars, or meteoric swarms. There are records of more than twenty new flaming stars, some of which were visible in the daytime. In November 1572, Tycho observed a star, called the Pilgrim, that suddenly appeared in the constellation of Cassiopeia, and at once became so brilliant that it could be seen at noonday. Such stars are called *Novae*. Two notable examples of them within recent years are Nova Aurigae of 1892 and Nova Persei of 1901. The latter was the most brilliant new star that has appeared since 1604. In three days it increased in brightness 25000 fold, and for a few hours was nearly as bright as Sirius. The writer had the pleasure of observing it when near its most brilliant phase.

All novae are temporary, and rapidly fade into nebulae. Nova Persei, following the usual course, became invisible to the naked eye in six weeks and its spectrum soon became nebular. So terrific was the heat evolved that the gases expanded outward with a velocity of over 2000 miles a second. Its distance was so great that its light, travelling with a velocity of 186,000 miles a second, reached us after a period estimated at 300 years, hence the collision must have occurred about the year 1600.

All visible fixed stars are gaseous suns, and the falling together by gravitation into direct impact of two such bodies would probably evolve insufficient heat to produce a nebula, unless the stars originally had considerable motion; but if the impact is only partial, so as to shear off limited portions from each star this matter would suddenly flame forth and expand into a gaseous nebula, while the two scarred stars would continue their courses at reduced velocities. Thus partial impact generally results in the birth of a third body of nebulous matter struck off from the meeting stars, and this new star with its momentum destroyed remains behind. If the amount sheared off equals one third of the mass, then three bodies of equal mass would result. It has been estimated by Bickerton that collisions between stars moving at the rate of 100 miles a second would produce a temperature of 100,000 degrees, depending to a certain extent on the elements contained in the colliding bodies. The runaway star known as 1830 Groombridge, has a motion of about two hundred miles a second.

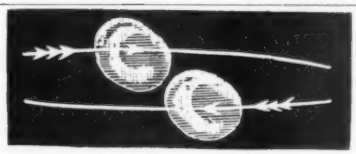


Fig. 1

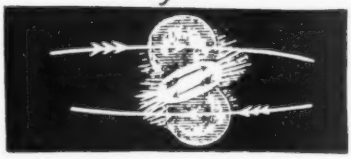


Fig. 2

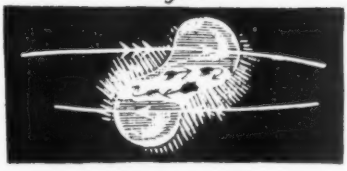


Fig. 3

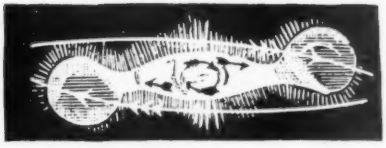


Fig. 4

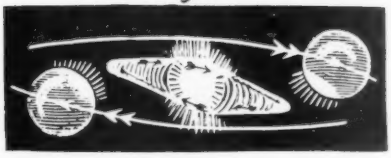


Fig. 5

Cuts showing an impact of two stars or dead suns which results in the formation of a temporary star that expands into a nebula.
Fig. 1. Pair of stars distorted by mutual attraction and coming into impact.
Fig. 2. Pair of stars in impact.
Fig. 3. Passing out of impact and forming a third body.
Fig. 4. Entanglement of matter before separation.
Fig. 5. A temporary star of very high temperature is formed, which finally expands into a nebula. Drawing by Bickerton.

It can be shown that stars may explode by near approach without actual impact. There is a well established law that where a body passes within a certain distance of a larger dense body it will be torn into fragments by differential attraction. This is called "the law of disruptive approach" and the limit of the distance that the two bodies must approach in order to produce disaster is called the "Roch Limit". Spiral nebulae are supposed to be the result of the near passage of two stars and the consequent explosive ejection of matter forming the two spiral arms containing nuclei at irregular points. Professor T. C. Chamberlin has shown that the bursting of the smaller body of two stars by near approach is from four to six times as imminent as by actual collision. He also calls attention to the fact that the disruption of a body like the Earth by near approach, where the interior temperature is much above the melting point and greatly compressed within by self-gravity, would cause it to burst forth into a luminous body with perhaps dispersive violence. Professor Chamberlin

further shows how the meeting of a solid with a gaseous body, where there is actual impact, may produce a nebula of the spiral form. He says, "The effects of explosive projection combined with concurrent rotation must obviously give rise to the spiral form. There should be two chief arms to the resulting spiral starting at opposite points of the central mass and extending outward to the limits of the spiral. The collision of dead suns in which disruption by approach preceded actual impact may play a part in forming irregular nebulae."

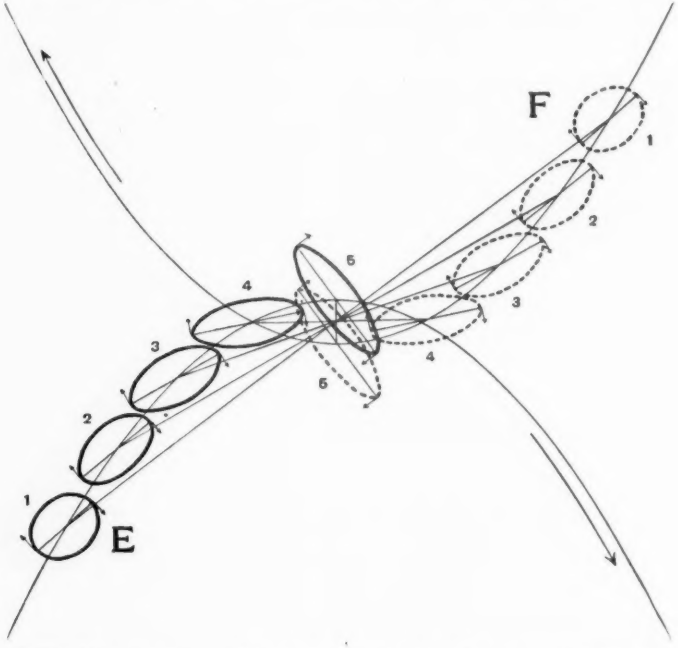


Illustration of the possible Function of Disruptive Approach in forming Spiral Nebulae.

The drawing shows the gradual elongation and the rotary effect of two gaseous stars E and F approaching perihelion. The straight line joining their centers indicates the direction of their mutual attraction. The stars collide by a shearing stroke. Here mutual explosive projection may result in the conversion of each star into a spiral nebula. The drawing is from the *Astrophysical Journal.*

No certain statement, as to the age of the Solar System, can be made. Astronomers now speak with less confidence than formerly of the age of the Sun, because the discovery of the

radio-activity of matter has led to the belief that it may play an important part in maintaining the Sun's effective heat. Lockyer says that the sun's spectrum proves that it has reached an advanced stage of development and is now on the decline by cooling. Its density is apparently much greater than stars of the Algol type, which indicates that the Sun has contracted by cooling more than they have, and is therefore on the downward grade.

To account for the immense number of bright stars, some effective means of regeneration must be postulated. No matter what time we may assume for the length of life of a star like our Sun, the whole previous history of the sidereal system must have been comparatively brief to account for its present status, without some process of renewal. By the clashing of suns the fire mists called nebulae are evolved, which condense into brilliant stars and organized systems. The wreckage of dead suns rekindles the heat of matter and gives perpetuity to the cosmic system. Unless there is some process of rejuvenation, all bright stars would slowly loose their heat energy, fade to darkness and finally reach the temperature of interstellar space, supposed to be about 300 degrees below the zero of Fahrenheit. The fact that the stellar universe has not attained a state of black refrigeration is conclusive proof of the existence of some process of renewal. The general conception of evolution is antagonistic to creation. The creation of matter is unthinkable, because the human mind cannot conceive of *nothing* becoming an object of consciousness. There is no evidence of creation, or even a beginning of the cosmic system nor is there promise of an end, the present is but a phase of an endless cycle in an immortal universe.

Recent researches regarding the theory of Laplace indicate that some of its details will require modification, especially those relating to the formation of planets from rings detached from the central mass of a nebula. Several astronomers now support a theory that the solar system was evolved from a nebula of the *spiral* form, notably Professors Chamberlin, Moulton, and See. The number of spiral nebula within range of the telescope is estimated at about 120,000 all of which may be embryo solar systems. Among the best known are the spiral nebula of Andromeda, the Great Bear, the Lion, Pegasus, Virgo, and Canes Venatici.

Professor See has in press a work on the "Evolution of the Stellar Systems", in which he presents his latest views on the

spiral nebula hypothesis. He endeavors to prove that the solar system was evolved from a spiral nebula in which the matter now forming the planets was not detached from the Sun, but was accreted from its spiral arms. The satellites were captured by the planets and not detached from the bodies around which they revolve. The Moon was originally a planet revolving around the Sun which on nearing the Earth was captured by gravitation, and has since remained a prisoner of the Earth.

In applying this theory to distant nebulae we must remember that during the time that the spirals of a nebula are supplying materials for the formation of planets, the nucleus is condensing into a sun, and after the evolution of the planetary system the most powerful telescope would only reveal the central sun as a fixed star, the planets being too small, and their reflected light too weak to be seen. In pursuing the study of the mechanism of the universe keep in mind that there are no empty spaces. Wherever we see a shining star there must be something connecting the star with the eye; a medium to transmit the light of the star. This medium is called ether, and its undulatory waves have a progressive motion, the effect of which produces the sensation of light. We say we have five senses, but we really have but one, this is the sense of mechanical contact, or feeling, or touch. The etherial waves sent out by the stars enter the eye and beat against the retina, whose sensitory nerves, acting as interpreters, communicate to the brain a translation of the impressions received. In a similar manner it could be shown that the other four senses are also the effect of mechanical contact.

Ether waves are sent out by the Marconi system to carry messages over the sea. Ether waves sent out by the stars bring messages to every part of the world. The stellar receiving instrument employed is called the spectroscope. The wit of man has never devised a more wonderful instrument than this receiver. The messages are not in the Morse code but come in the beautiful cipher of nature, illuminated with lovely prismatic colors. When the telescope of the spectroscope has been trained on a distant star, what information does the wireless message convey to the skilled spectroscopist? It informs him as to whether the star is single or double. If double, and the two stars are physically connected, it discloses their velocity of motion in line of sight, and tells the period of revolution of short period binaries around their common center

of gravity, and affords information as to the mutual distance and masses of the components. If the star is single and its motion rapid the message tells whether it is approaching or receding from us and reveals its radial velocity in miles per second. It tells its chemical composition and gives the elements as accurately as could be determined from a sample of the star in a laboratory. It further shows the approximate temperature of the star and imparts information as to many other things that cannot be entered into here.

In discussing the collision of stars it was stated that the resultant temperature from impact might reach 100,000 degrees Fahrenheit. The highest temperature that has ever been artificially produced is that in the narrow focus of the electric arc, estimated at 6000 degrees, which is far below the temperature of the coldest visible fixed star. The stars of the heavens have been found to be gigantic furnaces with temperatures enormously higher than any of which the chemist had dreamed. The fundamental mystery of chemistry was formerly the atom. The fundamental mystery of physics was the ether. Now the central mystery of chemistry, physics and electricity is the corpuscle. The chemist had dreamed of a single substance from which all the elements are compounded, and named it pantogen. This dream was realized by the discovery of radioactivity, which disclosed the fact that atoms instead of being indivisible are composite bodies made up of particles 1700 times lighter than than the smallest known atom. It requires 95000 corpuscles in fixed combination to form a single atom of iron.

When using the spectroscope it makes no difference whether the light under examination is that of a burning gas in the laboratory, or the light of a flaming star billions of miles away; both reveal their elements with equal clearness without regard to their relative distances. The spectroscopist has shown that in the extremely high temperature of stars matter assumes new forms in consequence of the dissociation of the atoms into corpuscles,

Sir Norman Lockyer has classified the stars in the order of their temperature. Stars of the hottest class called Argonian, from the star γ of the constellation of Argo Navis, which has a temperature estimated at about 55000 degrees F. The hottest stars of the Argonian type are in the infancy of their development. Here integration begins and increasing complexity of matter follows every stage of stellar development.

The Argonian stars are composed almost wholly of hydrogen

and proto-hydrogen, the latter being an imperfect or dissociated form of the gas. Alnilam, the middle star of the Orion girdle of pearls, is a leading example of stars of the hottest class. It contains but few elements, some of which are in the proto form. Its temperature is about 45000 degrees F. Following Lockyer's classification, and omitting for the purpose of brevity several classes, we come down to those represented by the great Dog Star, Sirius, whose temperature is probably 25000 degrees F. Here the number of components is greatly increased and metallic elements, in the proto form, begin to appear. In the eighth class of the Arcturian stars the temperature descends to about 15000 degrees F. which matches that of the Sun, both as to heat and elements. Finally, in Antares and stars of its class, the stellar temperature drops to about 9000 degress and there is a break in the phenomena in which light gases disappear and carbon predominates, associated with the heavy metallic elements. A marvelous knowledge of the chemical constitution of this class of stars has been attained.

The visible universe is a vast machine within which motions are being exchanged by contact and by radiation. The atom itself is as much a machine as a steam engine and both are thermo-dynamic motors. Heat is a motion of the atoms of matter and cooling slows down this motion, but the ingenuity of man has never brought a single atom to a state of rest. If all the heat of a body could be abstracted its atoms would cease to move. Matter at the absolute zero could not exist in either gaseous, liquid or in any known solid form, because its elements would fall apart, crumble into dust, and shrink enormously in volume. Increase of heat accelerated atomic motion until a critical velocity is attained that overthrows the affinities which hold the atoms in chemical combination.

At a temperature of 4000 degrees the existence of water is no longer possible, not even in the form of steam. Its molecules are unable to cohere because of their energetic motion, and they dissociate into hydrogen and oxygen gases. The temperature of a body varies as the square of the amplitude of vibration of its atoms. The heat of the Sun's interior is probably sufficient to dissociate nearly all chemical combinations, consequently solar matter is in its atomic or elementary condition. There is a still higher critical point, and perhaps a maximum temperature for matter, where the violence of the motion of clashing atoms causes them to break up into cor-

puscles. In stars of the highest temperature, like ζ Puppis, this critical motion of atoms has probably been reached, and a large part of the matter of such stars is in the corpuscular state. Each corpuscle has the same mass and same electric charge. Corpuscular matter is therefore in a state of perfect homogeniety; hence, we may say that inorganic progress consists in the change from the homogeneous to the heterogeneous and that the law of inorganic progress is the law of all progress.

When matter is in its hottest state it is at its lowest point in the scale of evolution, and all progress depends on a fall of temperature by radiation. Bickerton's and Chamberlin's theory of the enormous heat generated by stellar impact agrees with the result of Lockyer's spectroscopic study of the temperature of stars. Lockyer's inorganic evolution, joined to the spiral nebular hypothesis, and this to geological and biological evolution, complete the evolutionary cycle of the Earth to its present stage.

Organic life is possible only between the freezing and boiling points. Even a temperature of 140 degrees is destructive to the life of everything except the seeds and spores of a few microscopic organisms; hence in a total thermal range of perhaps 60,000 degrees, it is only within the one five-hundredth part this great thermometric scale that life can exist. It is in the same narrow limits of temperature that chemical action has its freest play, wherein there arises the greatest possible complexity of matter. Here the elements are combined in their most heterogeneous forms and matter is at its highest point in the evolutionary scale.

The end of all terrestrial life will probably come either by the violence of collision or by quiet refrigeration. Should no cataclysm occur, the Sun and planets would finally sink to a temperature of perhaps 300 degrees below zero. How remarkable it is that the delicate conditions for sustaining life should exist on our planet. It is said that a fall of even fourteen degrees Fahrenheit in the Sun's heat would be sufficient to produce a glacial epoch in our latitude, in which every vestige of life would be destroyed by the formation of ice a thousand metres thick.

In closing this brief article on the mechanism of the universe, I can not refrain from pointing to the lofty aims of empirical science, and to the rapid progress now being made through the critical investigation of the causes that underlie inorganic evo

lution. While the discoveries made in physical science during the nineteenth century developed our civilization to a marvelous height, the twentieth century promises to be still more fruitful.

Indianapolis, Nov. 18, 1910.

THE VISIBILITY OF VENUS BY DAYLIGHT.

EDWARD A. FATH.

The writer has for some time wished to learn for how long a time Venus is visible to the unaided eye by daylight. A favorable opportunity presented itself this year. The planet passed inferior conjunction on Feb. 11 at 19^h Greenwich Mean Time. On the morning of February 15 at $6^h\,45^m$ a. m. Pacific Std. Time or roughly Feb. $15^d\,3^h$ G. M. T. the planet was still visible to the unaided eye from Mt. Wilson when the Sun was 3° high. This was but 3 days 8 hours after conjunction with the Sun. Two days later Venus could be easily seen 35 minutes after the whole of the Sun's disk had appeared above the eastern horizon.

From this time on, the planet was noted at various times throughout the spring and summer. The last observation was obtained from Pasadena on the morning of Sept. 19, at which time the planet was easily visible 30 minutes after sunrise. I feel certain the time could have been extended at least two weeks more but clouds interfered. Thus at one elongation Venus was visible in full daylight to the unaided eye for 216 days, very nearly a complete sidereal period.

The only precautions taken at any time were to have the eyes in the shadow of a building, post, or similar object.

It might also be of interest to add that on Feb. 15 Jupiter was visible under the above conditions 20 minutes and on Oct. 14, Sirius could be seen 15 minutes after sunrise.

Mt. Wilson Solar Observatory.

Nov. 17, 1910.

ARE SPACE AND TIME INFINITE?

The Affirmative Answer.

C. H. AMES

The interesting grapple of Professor William Pickering, in a recent number of "POPULAR ASTRONOMY," with the old question: "Are space and time infinite?", suggests some reflections presented with the conviction that they furnish affiirmative and satisfactory answer, and one not requiring resort to the notion of a fourth dimension.

Professor Pickering wisely considers space first, as it is generally in connection with the idea of space that the difficulty of getting any satisfactory notion of the infinite presents itself. Every one recognizes that a finite space implies or presupposes larger space to exist in. So, on reflection, just as truly, does its environment. As we pass from one space to another we are still in space, and all finite spaces are parts of space itself,— the all comprehensive and necessary reality which makes finite spaces possible.

Hence, space is limited only by space, i. e. self-limited, i. e. universally extended and infinite. There is, and always must be, "space" beyond any and all "spaces," and when we say "always must be" we have the true, undeniable and perfectly satisfactory thought of the infinite. Why do we unhesitatingly say "and always must be?" This brings us to the most important distinction which it is possible for the mind to make, and the one which, when clearly perceived, will solve a vast number of knotty problems, and prove an emancipation of the mind from the unwelcome tyranny of one of our faculties which yet seems to so many persons to be unescapable.

It is true that most of the thinking of mankind is what might be called image thinking. It may even be admitted that most of it must be of this kind, and not only accompanied by, but in a sense dependent on, the image the mind makes of imagable things.

The question is whether there is another kind of thinking and a superior kind, which, whether *accompanied* or not by images, is not in any sense *dependent* on them for its cogency and reliability. It is certain that there is, and that even the ordinary, and perhaps not very reflective, man makes not

infrequent use of it, as, for example, when he says, of a repeating decimal, "and so on forever." We say that two and two are four. We hold the terms of this statement clearly in mind, and cannot frame a doubt of its certitude. But we quite as confidently affirm that two quintillions and two quintillions are four quintillions. What are the grounds of our certitude in the second case? We realize that it is our insight into "the nature of the case." In other words, it is our direct insight into reason, on which we rely, and not at all on our power to envisage or imagine the separate units of this stupendous sum.

Moreover, we know that the truth we have so positively stated not only is true now, but we are equally sure that it always was, and always will be, true, and that we have here a regal and transcendent power of the mind of a wholly different order from that which depends on the power to create images, which, in order to *be* images, *must* have borders and limits, and must, from their very nature, be finite.

Thus we may know thoroughly the *nature* of not only the finite but also the infinite. It is the power of reason, as contrasted with that of imagination. The mind then is capable, by the insight of reason, of knowing that which the imagination, from the nature of the case, is utterly powerless to cope with. It sees the infinite is never the indefinite, but the *self*-limited, and that this is a positive and satisfactory result. The indefinite is never the infinite, though almost universally it obtrudes itself when the infinite is spoken of. The indefinite is, when seen correctly, the *not yet defined*, but that which, for all that we know, may yet sometime be defined.

But the true infinite, of which we may have any number of examples, and of which we may make constant and most important use, e. g. in answering the question propounded by Professor Pickering, is never of that kind. Bearing its definition and nature constantly and unswervingly in mind, we may affirm, with utmost confidence and positiveness, that both space and time are truly infinite.

The mental protest which the imagination instantly makes is *only* the protest of the imagination, which not only may be but must be set aside as impertinent and meaningless in the light of our higher insight.

The effort of the imagination to find an end to space, or a beginning to time, may be seen from the outset to be futile. In such effort, the imagination, as Herbert Spencer truly says, "sinks exhausted," as we know it was doomed to do, and

its effort is not sublime but merely tedious and foolish, and in no wise throws doubt upon the deliverance of reason or presents any dilemma in regard to it.

If one should ask the shape of space, whether spherical or otherwise, his question dissolves in absurdity when he realizes that he is thinking of space, not as infinite, as we know it must be, but as finite, a space, requiring larger space, of the old fashioned sort, to exist in, and hence he is a victim of his imagination, and can be emancipated from this tyranny only by reliance on his reason. What is true of space in this regard is equally true of time, as will be readily seen. Space and time, then, are truly and positively infinite, despite the protest of the imagination.

In the light of this thought the difficulty found with the thought of time and space disappears. Professor Pickering says:—"Every one who considers the question of proceeding indefinitely along a straight line must feel the impossibility of coming to a point where there is no space beyond him, and yet at the same time he must feel that infinite space is itself an impossibility." We see that he has used the word "feel" for two entirely distinct and different things; in the first instance for a genuine insight of reason, a true perception of the "nature of the case," and in the second instance he uses the word "feel" for a mere protest of the imagination, which contains no truth whatever. We see also that his resort to a "curved space" by which to escape his dilemma is but another act of the misleading imagination, and no escape at all, for his curved space must exist in larger space of the familiar three dimension kind, and hence is not "space itself" at all, and that while we may speak of a "curved" or "spherical space" it is absurd to speak of space itself—the possibility of all particular spaces—as curved or spherical.

Professor Pickering says: "If it is difficult for us to imagine infinite space, it is still more so to comprehend infinite time. As we go back eternally through the ages, how is it possible for there to be still an infinity of time before that? Yet we cannot conceive of an actual day or instant before which time did not exist."

We see that in these few lines the author has used the terms "imagine," "comprehend" and "conceive" as interchangable and without difference of meaning. It is, therefore, not surprising that he is led into such mental tangles as follow, and in which he has recourse to such grotesque and, as Herbert

Spencer says, only "verbally intelligible" expressions as those relating to time and space so "curved" that they return into themselves.

An excellent example of the persistent way in which the imagination asserts itself when one supposes himself to be independent of it is furnished by Professor Pickering's remark that "to a reasonable mind unfamiliar with our universe space of four dimensions would appear to be *a priori* quite as probable as space of three."

Here is the naive assumption that one familiar with our universe, and of course thinking according to the methods of our universe, and the methods of the only "reasonable minds" that we can possibly know anything about, can predicate anything of a "reasonable mind unfamiliar with our universe." It is another example of a "merely verbally intelligible" statement. Our author might, with equal propriety, have added that to such a "mind" the idea of no space at all of any kind would be equally "probable." The truth is that we can think of mind only in terms of our own minds, and we cannot even conceive, logically, of anything whatever outside of those terms, and whatever may be outside of that cannot be the subject of assertion or even conjecture on our part.

Whatever logical value there may be for mathematicians in the theory of a space of four dimensions, or even more dimensions than four, there seems to be no help for Professor Pickering in that theory, or reason why he should bring it into his discussion. His conclusion is, however, that "it is either the fourth dimension or infinity," and he asks "which is more likely?" It is the contention of this article that the trouble with the notion of infinite space is but the protest of the imagination and, therefore, negligible, and that, therefore, the recourse to notions of a curved space and even a curved time, of such nature that "if we could go back far enough into yesterday, we shall arrive at tomorrow," is as needless as it is fantastic and absurd.

In struggling to escape from some of the coils, which such reliance upon the imagination involves one in, Professor Pickering suggests "a clue to our method of escape" that in the early history of each star there may have been a time when gravitation had no effect. He, however, seems to appreciate the utter bewilderment of thought to which his words bring him and admits "we are now, however, far beyond our depth in the unknowable, and suggestion even at this point seems fruitless."

Yet it is to just such a condition of bewilderment that one must come if he does not see clearly the difference between the two faculties of imagination and reason. It will be found moreover that a clearing up on this point will be of unexpected and far reaching importance, not only in the problems of physics, but those of pure philosophy, and that the importance of such a clearing up, possible to any persistent thinker, cannot be overestimated.

DR. SEE'S NEW THEORY OF STELLAR AND PLANETARY EVOLUTION.*

ERIC DOOLITTLE.

For Popular Astronomy

The magnificent piece of research work which we are about to review is the outcome of nearly twenty years of that unflagging energy and zeal which is characteristic of its author. All astronomers, whatever their views may be, must extend to him their congratulations on this work he has so successfully completed, a work demanding an originality of thought, a thorough mathematical ability, and patient labor extending over many years, of which all too few are capable.

To adequately review in a small space the 735 quarto pages of this volume is obviously not possible. We will, however, try to give the reader some indication of the scope of the book, and to state for him as briefly and clearly as possible the fundamental theory, to the development of which it is principally devoted.

The work is entitled "The Capture Theory of Cosmical Evolution," but it is really much more than this. The student will find here a clear statement of the restricted problem of three bodies, with a description of several of the celebrated periodic orbits of Hill and Darwin, an account of the very interesting work of Darwin on non-periodic orbits, and an extension by Dr. See of these researches, which consists of an inquiry into the effect produced by the presence of a resisting medium. And in this connection the simpler methods of treat-

* Researches on the Evolution of the Stellar Systems, Vol. II. By T. J. J. See, quarto pp. 735. Press of Thos. P. Nichols & Sons, Lynn, Mass. 1910.

ing the violent perturbations of a comet upon its near approach to a planet are also fully described.

One chapter is devoted to Darwin's theory of tidal evolution with the modern criticisms of it. In another the complete differential equations, the areal integrals of which lead to the conception of the invariable plane, are derived, and the position of this plane is determined with the highest accuracy which is at present attainable. There is also a chapter on the physical constitution of the heavenly bodies, in which the so often quoted but little known theory of Lane is developed, and the series for finding the densities at different depths below the Sun's surface are extended to terms of the fifty-first order by Dr. See in order that his computations from these series may have the highest possible accuracy. And naturally following this, there is the investigation of the temperatures of the Sun and stars, and a most striking and valuable research into the rigidity of the heavenly bodies.

In short, from one point of view, much of the book might be regarded as a very clearly written chapter of Celestial Mechanics, which treats of many things which cannot be found elsewhere and which could be read with much pleasure by every student moderately acquainted with the higher mathematics. But all of this and very much more is here developed for its bearing on the remarkably important and far-reaching theory which is the outcome of so many years of research by Dr. See. This is a theory not alone of the evolution of the Solar System, but of the distribution of the nebulae and star clusters, and of the structure of the sidereal universe itself. Before reviewing the whole work in detail it may be well to give a very brief account of the Capture Theory and a few of the many facts which are explained by it.

There are two causes which have been remarkably neglected by former investigators in this and allied studies in astronomy, but which Dr. See shows are of the highest importance. These are the repulsive forces of nature and the action of a resisting medium. It is by the former that the very finely divided matter constantly expelled from the more mature stars is driven toward the poles of the Milky Way, where the stars are fewest and where nebulae are ultimately formed by the gathering o this matter together. It is by the latter that the gradua coiling up of the nebulae into spiral forms and the development of true solar systems from spiral nebulae of great extent extending is explained.

The original solar nebula was of immense size, probably extending to one thousand times the distance from the Earth to the Sun. At many parts of its immense extent, condensations of the cosmical dust to many centers would slowly go on, while the nebula was still so diffused that the neighboring centers would have but little disturbing action upon one another. As all the material shrank together under its gravitating action it would become arranged in spiral streams, a little curved near the outer boundary but becoming more circular near the center. Neither the centers of condensation nor any particle of the nebula would move along the spiral arms which we see, but each would pursue its own path, revolving incessantly against the resisting medium.

This resistance would have two very important effects. First, it would continually decrease the radii vectores and thus build up the central mass, until it began to exert an attraction sufficient to cause the particles to move approximately in ellipses. And secondly, when the central mass had thus become predominant, the resistance would decrease both the major axis and the eccentricity of each orbit. As the planet moving always against the resisting medium neared the Sun, it would in time sweep up the cosmical dust from a wide zone and thus the system would gradually be cleared of nebulosity.

If we examine the satellite systems we find that those which have been forced down very near their primaries, such as the four satellites of Uranus, move in orbits which are very nearly circular, while the orbits of those which are still far distant are eccentric. The resistance of the medium through which they move also beautifully accounts for the rapid revolution of the inner ring of Saturn and of the inner satellite of Mars.

The particles which revolved around the original centers of condensation might equally well revolve in any plane, since there is nothing which could cause them to take one position rather than another. But as the center gradually dropped nearer the point of greatest condensation of the slowly rotating nebula, its axis of rotation would tend to come more and more into a position at right angles to the plane of rotation of the whole, and the more material it gathered up the more marked this effect would be. Thus the obliquity of only three degrees which is seen in Jupiter is accounted for and the high obliquities of Neptune and Uranus, near the outer edge of the solar nebula, are what might be expected according to the theory.

The more material which a planet gathered up the faster the planet would rotate, since the surface velocity of no planet even nearly approaches the velocity of a satellite revolving just above its surface; and this also is in accordance with what is seen, the times of rotation of Jupiter and Saturn being very short and those of the smaller planets much longer.

Not only are the circularity of the orbits, the common plane of rotation, the satellite systems, the obliquities, and the times of rotation thus explained, but the distribution of the various planets is also to a great extent accounted for. For while there may have been very many terrestrial planets which became part of the Sun, it is very doubtful whether so large a planet as Jupiter could have approached very near the center of the nebula without the consequent diminution of its major axis having destroyed it as an independent body. And of the many inner planets only those having unusually round orbits have survived; the rest are now part of the Sun, their destruction having doubtless been aided by the perturbing action of Jupiter. So that the inner part of our system has been left comparatively very vacant. These are a few of the more striking confirmations of the theory which are adduced by Dr. See, but for anything like an adequate understanding of it the reader should follow the mathematical development and the reasoning of the book itself. And to a brief description of the contents of the book we will not proceed.

As it is assumed that the solar nebula was originally of a spiral form, the first two chapters are given up to a consideration of all the more simple spirals which may occur. It is readily shown that no particle can move in these paths except under the action of very complex attractive forces which do not occur in nature, and also that the spirals shown on photographic plates are not identical with any simple spirals. Those of the more extended nebulae resemble the logarithmic spiral, but when the nebula becomes more condensed and the convolutions crowded more closely together the form approximates to that of the spiral of Archimedes. At any time the spiral is a Chance Spiral, representing one step in the coiling up of the nebulous cloud.

There next follows an investigation of how either two nebulous clouds encountering one another, or a single nebula shrinking under its own gravity, may come to take a spiral form, and as this is assumed to have been the mode of origin of all of the stars, it is regarded as exceedingly probable that

all stars which are not double or multiple have planetary systems revolving around them.

In the next chapter the distribution of the nebulae is considered, and the apparent antipathy between the stars and nebulae is especially dwelt upon. It is here that the most striking objections to the well known theory of Chamberlin and Moulton are considered. It will be remembered that according to this theory the spiral nebulae are formed by the near approach of two stars, one or both of which are disrupted by the pull which they exert upon one another. But if this is the true origin of these nebulae they should be most numerous where the stars are the densest, that is in the Milky Way and in dense clusters, because close approaches would there occur most often. Yet the majority of the spiral nebulae are found near the poles of the Galaxy, that is, where the stars are least numerous. Another weighty objection to this theory is the theoretically extreme infrequency of such near approaches of stars: "About once or twice in a universe of one hundred million stars", is the estimate of Professor Crawford. And finally, that tidal disruption could in this way generate nebulæ thousands of times larger in extent than the whole solar system seems improbable.

A mathematical development of the secular effect of the action of a resisting medium is next given. It is proved that under the single assumption that the nebula increases in density according to any law as the center is approached, the eccentricities of the orbits of all bodies moving in the nebula will be diminished. Then follow three chapters containing a most clear and interesting review of the periodic and non-periodic orbits of Hill and Darwin. These beautiful investigations, so well known to the student of modern work in Celestial Mechanics, are, of course, all made under the supposition that the motion takes place in empty space. Dr. See shows that, in consequence of the resistance actually present, the Jacobian integral upon which the curves depend must have added to it a secular term dt; the complete equation then shows that when the particle is found within the hour-glass space enclosing both bodies, it may drop nearer the attracting center and become captured. A simple consideration of the figures shows too that a satellite so captured can hardly survive if it approaches near to the planet, unless its motion is direct; the motion of a more distant satellite may however be retrograde. In this manner it is believed that our own Moon was captured:

Darwin's theory of the terrestrial origin of the Moon, together with Moulton's criticisms of it are fully given, the final conclusion being that as this theory must be abandoned there remains little evidence that either the Earth or the Moon ever rotated much more rapidly than they do at present.

The next chapters are taken up with a discussion of the outstanding inequality in the secular acceleration of the mean motion of the Moon, and it is inquired whether this may not be indirectly caused by the effects of streams of cosmic dust through which the lunar terrestrial system is moving.

The complete outline of the new theory of the development of the solar system then follows, after which there is given an account of the researches into the physical conditions and rigidities of the heavenly bodies. Of most striking interest here is the conclusion that even with the enormous temperature of the Sun, the whole interior is under such pressure that it behaves exactly as a solid. The layer which behaves as a gas can scarcely have a depth equal to one tenth of the radius, and as convection currents could not be maintained in a rigid solid, it follows that these only exist in the outermost layers of the Sun's globe. The supply of light and heat is thus maintained by direct radiation from below. The complex system of convection currents sinking to great depths in a large mass of high average rigidity is thus replaced by a much simpler process.

In the same manner it is found that the ball of the Earth is more rigid than steel, but that this great rigidity is wholly due to the great pressure: if at only a moderate depth the pressure could be removed, it is believed that the ball would become vaporized at this point by the great internal heat. And it also follows that even when the Earth was liquid its rigidity under pressure was so great that it yielded to tidal action but very little more than it does now.

The remainder of the book is given up to an examination of nebulae, star clusters, and the structure of the Milky Way under the light thrown by the new theory upon these objects.

It is evident that the large, formless nebulae are so enormously extended that for very many ages to come their gravitating force will be too feeble to make evident any general flow of their material about a central nucleus. There can be no doubt that in time, however, this will occur, but the extent of these objects is so very great that it is believed that their development will be into star clusters rather than into single systems. And it is believed to be certain that

those which are already comparatively small enough to show the typical spiral about a central nucleus, are not masses of fluid in equilibrium under hydrostatic pressure, but discontinuous vortices circulating and condensing into systems.

In the great clusters, and even in the Milky Way itself, this clustering power is ever acting and its effects are clearly indicated. This is especially seen in the beautiful photographs by Barnard of the star clouds of the Milky Way, which are doubtless familiar to all readers. But Dr. See emphasizes the very important part played by the resisting medium in this clustering tendency, the effect of which is to render far more effective the feeble action of gravitation and to hasten, not only the formation of single systems, but the aggregation of these into more or less compact clouds and clusters. The appearance of the whole Milky Way itself is thought to be well explained by the assumption that its structure is of a spiral form. The vortex of the spiral as viewed from our Sun lies in the direction of Sagittarius and our Sun is carried by the streaming of the material about this center in the direction of the constellation Hercules, as was long ago pointed out by Herschel.

In nebulae of any extent there are thus many centers of aggregation which, at least in the smaller nebulae, are gradually drawn nearer the central mass by its gravitation combined with the action of the resisting medium. This gradual building up and drawing together of the bodies of a system Dr. See has called development by capture. This name well distinguishes the new theory from those theories which are based upon the assumption that the attendant bodies were originally a part of the central mass and were left behind or driven off as the system developed. The detachment theory of LaPlace, which held its place in astronomy for so many years, has long ago been definitely disproved in all of its essential features.

We can perhaps do no better than close a brief review of this very valuable and extended research in the words of Dr. See himself:

> "One true principle gives unity and mental connection to millions of isolated facts, and it is only by means of such principles that the observed facts can be interpreted. The Capture Theory is so overwhelmingly indicated by the most diverse phenomena of the starry heavens that I cannot doubt that it represents an ultimate truth....The most

varied celestial phenomena indicate that the grand order thus disclosed probably is the sublimest of all cosmical processes,"

The Flower Observatory, Dec. 1, 1910.

DISTRIBUTION OF THE STARS IN SPACE.

H. C. WILSON.

In the Proceedings of the Royal Society (London), series A, Vol. 84, p. 47, Professor Karl Pearson gives an extended paper "On the Improbability of a Random Distribution of the Stars in Space". By a long mathematical discussion, none of which can be given here he reaches two remarkable conclusions:

(1.) *The mean of any random selection of stars not including any over the m_0 magnitude ought to be 0.7238 of a magnitude below this limiting value, if the stars are distributed uniformly through space.*

That is to say, the average of the magnitudes of all the stars brighter than magnitude 6.0 should be 5.2762 and of those brighter than 10.0 should be 9.2762. etc.

(2.) *The standard deviation of the magnitudes of a series of stars cut off at a given magnitude is constant, whatever that magnitude may be, and equal to the normal value of the $25\sigma P^2$ parallax constant.*

By the standard deviation is meant the square root of the mean of the squares of the deviations of the magnitudes of the whole series of stars from their average magnitude. The quantity σP has a similar meaning with reference to the logarithms of the parallaxes of the stars.

Expressed in equations the two formulæ are written by Professor Pearson.

$$(1) \qquad \overline{m} = m_0 - 0.7238$$

$$(2) \qquad \sigma_m{}^2 = 0.5240 = 25\,\sigma P^2$$

Applying these formula to the data contained in the *Annals of Harvard College Observatory* vol. 48, "Distribution of the Stars", which contains accurate counts and magnitudes of stars down to magnitude 7.25, the results are obtained which are given in the following table.

Up to magnitude.	Number of stars.	Mean magnitude Observed.	Mean magnitude Theoretical.	Square standard deviation. Observed.	Square standard deviation. Theoretical.	Differences Δm	Differences $\Delta\sigma_m{}^2$
0.25	5						
0.75	10						
1.25	18						
1.75	32						
2.25	58	1.440	1.526	0.423	0.524	−0.086	−0.101
2.75	105	1.914	2.026	0.512	0.524	−0:112	−0.012
3.25	193	2.409	2.526	0.571	0.524	−0.117	+0.047
3.75	336	2.874	3.026	0.619	0.524	−0.152	+0.095
4.25	589	3.357	3.526	0.664	0.524	−0.169	+0.140
4.75	1067	3.869	4.026	0.689	0.524	−0.157	+0.165
5.25	1972	4.388	4.526	0.691	0.524	−0.138	+0.167
5.75	3562	4.885	5.026	0.688	0.524	−0.141	+0.164
6.25	6284	5.368	5.526	0.695	0.524	−0.158	+0.171
6.75	11004	5.853	6.026	0.711	0.524	−0.173	+0.187
7.25	17955	6.297	6.526	0.748	0.524	−0.229	+0.224

Concerning these results Professor Pearson says: "It will be obvious from this table that while our formulæ express approximately the truth (never differing by a quarter of a magnitude from it), yet the observed values differ sensibly and almost regularly from the calculated values—the higher the limiting magnitude the greater is the divergence. That is to say, the more stars we take into our consideration, the less accurate appears to be the assumption of the uniform distribution of the stars through space. I think we are fully justified on the basis of this table in stating that a random distribution of the stars through a spherical space is inconsistent with the observed facts. Or, if such a random distribution exists, then there must be a correlation between distance and intrinsic brilliancy. Such an apparent correlation would be produced, of course, if light were to any extent absorbed in transmission through space. The few stars of lower than third magnitude may be reasonably supposed uniformly scattered through space, since they fairly closely satisfy the necessary conditions; beyond this magnitude we have *continuous* deviations which cannot possibly be looked upon as the random or irregular variations from a chance scattering."

Applied to the list of double stars in Burnham's General Catalogue, the formulæ give still wider divergence from the observed mean magnitudes, but this is to be expected, since a far larger proportion of the bright double stars have been discovered than of the faint ones, and the limits as to angular separation are much narrower for faint doubles than for bright ones.

The lists of known parallaxes of stars are too small to yield trustworthy averages, but from 69 out of 72 stars listed by Newcomb in "The Stars," and 122 out of 163 stars observed at Yale, Professor Pearson gets the following results, rejecting negative parallaxes:

	V_d	$V\pi$	$25\sigma P^2$
Normal System	0.258	0.577	0.5240
Newcomb Stars	1.075	0.924	4.212
Yale Stars	1.017	1.443	3.111

V_d and $V\pi$ represent the ratios of the standard deviations in distance and parallax to their corresponding mean values. Both the Newcomb and Yale stars, while agreeing fairly well with each other, exhibit wide variations from the theoretical numbers.

In the course of his paper Professor Pearson suggests that the two formulæ which we have quoted may possibly be derived by much simpler processes than he has used. In a later number of the Proceedings of the Royal Society (series A, vol. 84 p. 369) Professor F. W. Dyson, now Astronomer Royal of England, gives a shorter derivation, although it is not easy to follow in the brief form in which it is given. His method is as follows:

The formula $\overline{m} = m_0 - 0.7238$ and $\sigma_m^2 = 0.5240$, are immediately deducible from the proposition that for a uniform distribution of stars, and assuming no absorption of light, the total number of stars down to magnitude m is given by

$$\Sigma m = C\,(2.512)^{\frac{3}{2}m} = C\,(3.99)^m.$$

In this well-known formula, 2.512 is the ratio of the amount of light received from two stars which differ by one magnitude. A formal proof of the formula may be given as follows:—

Let $\phi(m)$ be the nnmber of stars contained in unit volume, as seen from unit distance. A thin spherical shell of radius r will contain $\phi(m).\,4\pi r^2\,dr$ of such stars.

Now if a star is of magnitude m at unit distance, its magnitude at the distance r is $m - 5\log_{10} r$. Thus $\phi\,(m - 5\log_{10} r)\,4\pi r^2 dr$ equals the number of stars in the shell which, seen from the center, appear to be of magnitude m. Therefore the total number of stars down to magnitude m is given by

$$\Sigma m = \int_0^\infty \phi\,(m - 5\log_{10} r).4\pi\, r^2 dr$$

The number of stars down to the next magnitude $m+1$ will be

$$\Sigma(m+1) = \int_0^\infty \phi\,(m + 1 - 5\log_{10} r).\;\; 4\pi\, r^2 dr$$

$$= k^3 \int_0^\infty \phi\,(m - 5\log_{10}\frac{r}{k}).4\pi\,\frac{r^2}{k^2}\;d\left(\frac{r}{k}\right),$$

replacing 1 by $5 \log_{10} k$ and multiplying and dividing by k^5. This equation is in the same form as the one above, $\frac{r}{k}$ taking place of r. The limits of $\frac{r}{k}$ are the same as those of r; therefore

$$\Sigma (m+1) = k^3 \Sigma m$$

and the number of stars down to each magnitude is obtained by multiplying the number down to the preceding magnitude by the constant k^3, which equals the number whose logarithm is 0.6, or 3.98 +. In this way, starting with C as the number of stars of zero magnitude and brighter,

$$\Sigma m = C (3.98 +)^m = C (2.512)^{\frac{3}{2}m}$$

Writing this in the form $\Sigma m = C\epsilon^{\lambda m}$ and differentiating

$$dm = = \frac{d \Sigma m}{\lambda \Sigma m} .$$

Considering the mean magnitude multiplied by the total number of stars down to the limiting magnitude as an integral,

$$\overline{m} \Sigma m_o = \int_0^{\Sigma m_o} m \, d\Sigma m = m_o \Sigma m_o - \int_{-\infty}^{m_o} \Sigma m . dm$$

$$= m_o \Sigma m_o - \int_{-\infty}^{m_o} \lambda^{-1} \, d\Sigma m = (m_o - \lambda^{-1}) \; \Sigma m_o$$

Since $e^{\lambda} = 3.98$, $\lambda \log_{10} e = 0.6$ and $\lambda^{-1} = \frac{0.434294}{0.6} = 0.7238$

Therefore $\overline{m} = m_o - \lambda^{-1} = m_o - 0.7238$

In a similar manner for the standard deviation of the magnitudes from the mean

$$\sigma_m \Sigma m_o = \int_0^{\overline{m}} (m - \overline{m}) \, d\Sigma m$$

$$= 0 - \int_{-\infty}^{m_o} \Sigma m . dm = \lambda^{-1} \Sigma m_o$$

$\therefore \sigma_m = \lambda^{-1}$ and $\sigma_m^2 = \lambda^{-2} = (0.7238)^2 = 0.524.$

For the derivation of the formula for the number of the stars down to any given magnitude the writer of the present note prefers a method which does not involve the use of the infinitesimal calculus, since its application to widely scattered bodies in space of infinite extent may admit of question.

If the stars are scattered uniformly through space it is clear that, regardless of their sizes or brightness, the total number in a given spherical space will be proportional to cube of the radius of the sphere that is

$$N = Cr^3 \qquad (a)$$

N being the total number, C a constant and r the radius of the spherical space

The light which we receive from a star is in inverse proportion to the square of its distance, so if l_m represent the light which we receive from a star of magnitude m at a distance r, and l_1 the light we would receive if the star were at a distance unity

$$l_m = \frac{l_1}{r^2} \qquad (b)$$

Again since the ratio of light from magnitude to magnitude is 2.512, if l_o represent the light which we receive from zero magnitude star

$$l_m = \frac{l_o}{(2.512)^m} = l_o\,(2.512)^{-m} \qquad (c)$$

Eliminating l_m from equations (b) and (c) we obtain

$$r = \left(\frac{l_1}{l_o}\right)^{\frac{1}{2}} (2.512)^{\frac{1}{2}m} \qquad (d)$$

The stars of a given magnitude are not all of the same size or intrinsic brightness, therefore they are not of the same distance, but when great numbers of stars are considered there will be an average distance for those of each magnitude and an average size and intrinsic brightness for the stars of all magnitudes. Taking these averages we may write in place of (d)

$$r_m = c\,(2.512)^{\frac{1}{2}m} \qquad (e)$$

and substituting in (a)

$$N_m = cC\,(2.512)^{\frac{3}{2}m} = C_1\,(3.98)^m$$

ASTRONOMICAL PHENOMENA IN 1911

ECLIPSES.

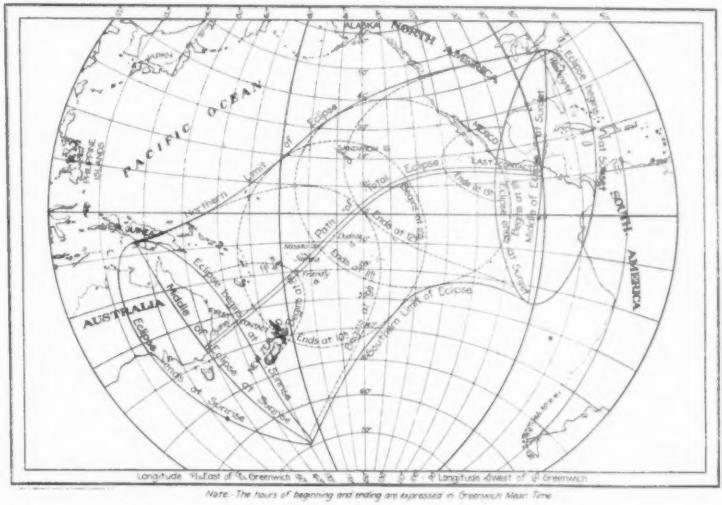
There will be but two eclipses, both of the Sun, during the year 1911. The first, on April 28, 1911 will be total, beginning in southeast Australia and ending off the coast of Central America. It will be visible as a partial eclipse in the southeastern part of the United States at sunset. The second, on October 21, 1911, will be annular, beginning in Western Asia and ending in the Pacific Ocean near the Fiji Islands. The following data are taken from the *American Ephemeris*:

(1) *A Total Eclipse of the Sun*, 1911, April 28, visible at Washington as a small partial eclipse, the Sun setting eclipsed.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of ☌ in right ascension, April $28^d\ 10^h\ 16^m\ 25^s.3$.

Sun and Moon's R. A.	2^h	20^m	$32^s.79$	Hourly motions	$9^s.47$ and	$139^s.53$	
Sun's declination	14°	1′	8″.8 N	Hourly motion		0′	47‴.5 N
Moon's declination	13	45	54.2 N	Hourly motion		15	16. 9 N
Sun's equa. hor. parallax			8.7	Sun's true Semidiam		15	52. 8
Moon's equa. hor. parallax	60		32.4	Moon's true semidiam		16	29. 0



Note. The hours of beginning and ending are expressed in Greenwich Mean Time

CHART OF SOLAR ECLIPSE OF APRIL 28, 1911.

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time			Longitude from Greenwich		Latitude	
	h	m	s	°	′	°	′
Eclipse begins	April 28	7	49.1	161	10.5 E	32	19.3 S
Central eclipse begins	28	8	46.0	148	37.3 E	36	47.9 S
Central eclipse ends	28	12	8.9	90	2.3 W	11	5.9 N
Eclipse ends	28	13	5.7	103	2.4 W	15	38.5 N

(2) *An Annular Eclipse of the Sun*, 1911, October 21, invisible at Washington.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of ☌ in right ascension, October 21^d 15^h 54^m 33^s.6.

Sun and Moon's R. A.	13^h 42^m 36^s.42		Hourly motions	9^s.46 and	116^s.57
Sun's declination	10° 38′ 11″.8 S		Hourly motion	0′	53″.6 S
Moon's declination	10 18 1 .4 S		Hourly motion	14	10 .1 S
Sun's equa. hor. parallax	8 .8		Sun's true semidiam	16	4 .4
Moon's equa. hor. parallax	56 5 .1		Moon's true semidiam	15	16.2

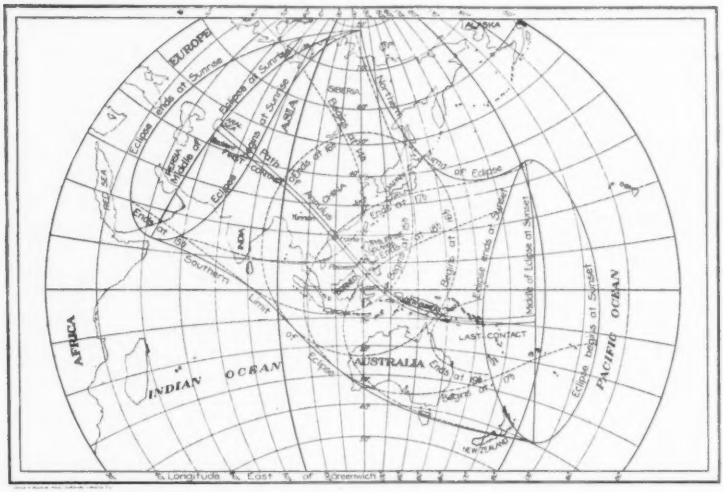


CHART OF ANNULAR ECLIPSE OF OCTOBER 21, 1911.

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time			Longitude from Greenwich		Latitude	
	h	m	s	°	′	°	′
Eclipse begins	Oct. 21	13	19.5	77	44.7 E	38	4.1 N
Central eclipse begins	21	14	25.5	60	31.1 E	44	44.8 N
Central eclipse ends	21	18	0.7	177	29.0 E	7	50.2 S
Eclipse ends	21	19	6.7	162	18.5 E	14	37.5 S

The regions within which these eclipses are visible are laid down on the accompanying charts, from which, by means of the dotted lines, the Greenwich times of beginning and ending at any place may be found with an uncertainty which will vary from three or four minutes for a high Sun to fifteen or twenty minutes when the Sun is near the horizon.

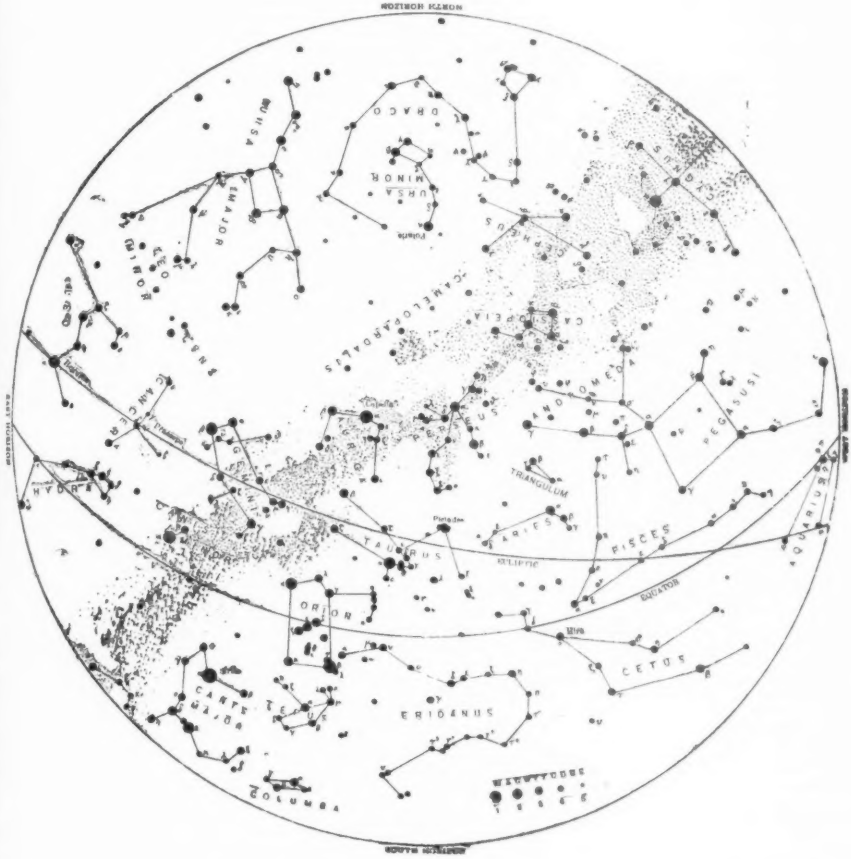
THE PLANETS.

The apparent paths of the planets through the constellations for the year are given upon the charts Figures 1 and 2.

Mercury begins the year with retrograde movement, making a loop in Sagittarius as it passes between the Earth and the Sun in January. After that its course is eastward along the ecliptic until the latter part of April,

when it makes an S-shaped loop in Aries, the retrograde movement lasting through the first half of May. Another loop, this time a closed one in Leo, is made in August and September and a fourth is half finished in December, to be completed as the planet starts out on its course for 1912.

The following table gives the times of conjunction with the Sun and of greatest eastern and western elongation from the Sun, together with the phase of the planet and the brilliancy number of its disk at the times of greatest elongation. From this table it appears that the planet will be faint at the elongation in August when it will be farthest out from the Sun and in most favorable position for observation in the evening. It will be brightest at the western elongation in September when it will be visible in the morning.



THE CONSTELLATIONS AT 9:00 A. M. JANUARY 1, 1911.

CONJUNCTIONS			GREATEST ELONGATIONS.			
Inferior	Superior	Eastern	Western	Angle from Sun ° ′	Phase	Light
Jan. 19	Mar. 19	...	Feb. 1	25 18	0.60	38
May 5	July 3	Apr. 14	...	19 43	0.40	49
Sept. 8	Oct. 23	...	June 1	24 30	0.38	34
Dec.. 24	...	Aug. 12	...	27 26	0.50	32
...	...	...	Sept. 24	17 52	0.46	61
...	...	Dec. 7	...	20 59	0.62	51

Venus begins its course in Sagittarius and moves eastward along the ecliptic until August when, for the rest of the year, it describes a closed loop in Leo close to that of Mercury. It will be at greatest elongation, east from the Sun 45° 29′, on July 6, at inferior conjunction September 14, and at greatest elongation, west from the Sun 56° 45″ on Nov. 25. Its greatest brilliancy will be about August 9, before conjunction and October 22, after conjunction.

The course of *Mars* begins in Scorpio, and follows the ecliptic, approximately, eastward until October, when it slows up and forms a large loop in Taurus, which is not completed at the close of the year. Mars will be at opposition on November 24, and at its nearest approach to the Earth on November 16, when the distance will be about 47,500,000 miles and the apparent diameter of the planets disk 19″.6.

Jupiter's path will be found to lie chiefly in the constellation Libra, although it enters the southeastern corner of Virgo for a time in the summer and closes the year in Scorpio. The planets course is eastward until March, westward until July, then eastward for the remainder of the year.

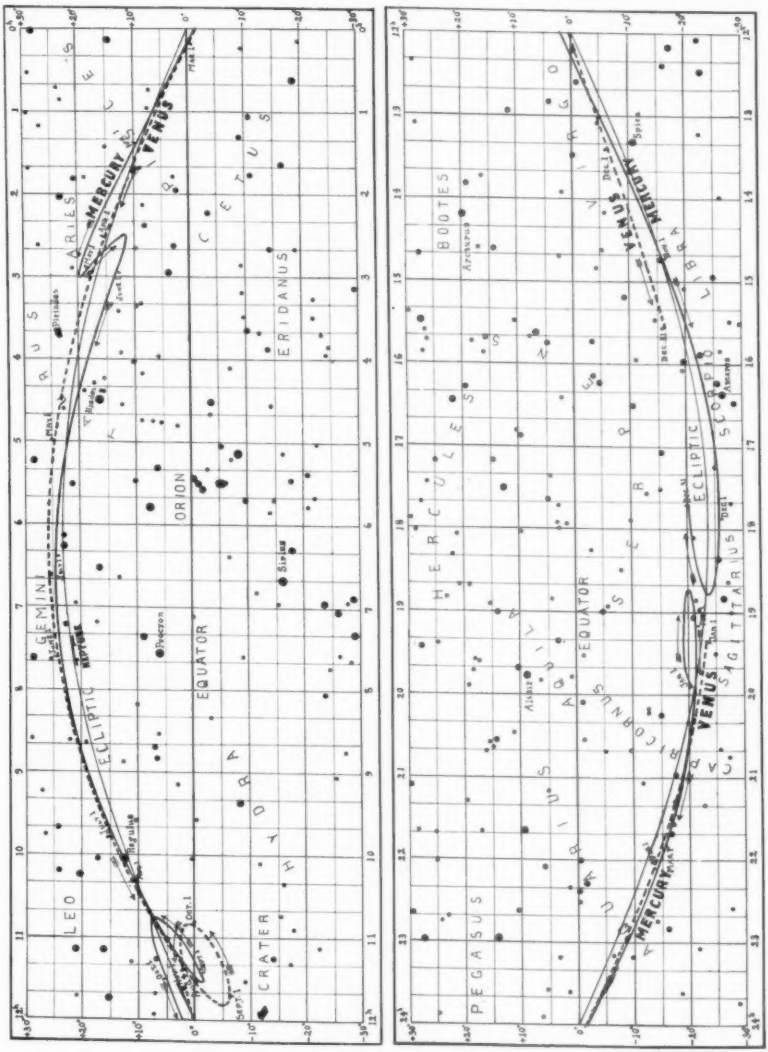
Saturn starts from a point in Cetus a little way east of α Piscium and travels eastward until September, then westward for the rest of the year. The path of Saturn coincides for much of its length so closely with that of Mars in July and August that the two could not be drawn separately on the chart. There will be a close conjunction of the two planets on the night of August 16.

The path of *Uranus* is only about five degrees long in the eastern part of Sagittarius. On the chart it lies between the ecliptic and the path of Mars, so that it might be overlooked were it not for the name printed above it. The motion is eastward until May, then westward until October, then eastward for the rest of the year.

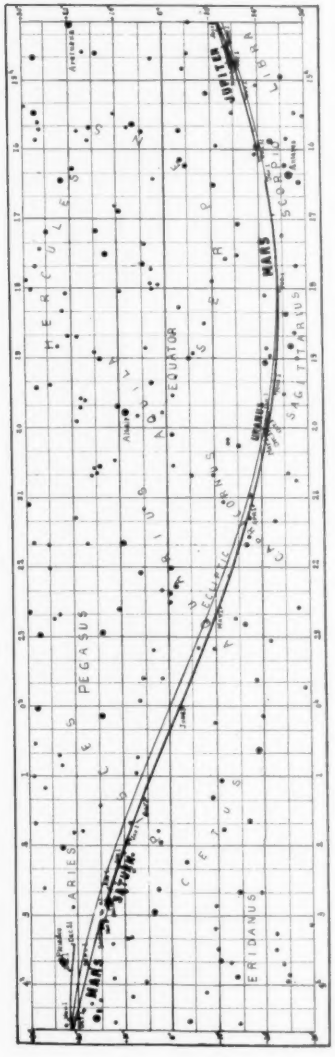
Neptune's path will be found on the chart of the path's of Mercury and Venus. It is also short, about 5° long, in Gemini, the movement being westward until April then eastward up to October 28, then westward for the remainder of the year.

OCCULTATIONS VISIBLE AT WASHINGTON.

Date 1911	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration h m
Feb. 8	125 Tauri	5.1	14 40	134	15 18	230	0 39
10	c Geminorum	5.5	12 23	80	13 25	316	1 2
13	46 Leonis	5.8	8 10	101	9 16	305	1 6
16	k Virginis	5.7	10 20	89	11 15	337	0 55
17	575 B Virginis	6.2	11 54	69	12 34	3	0 39
19	147 B Librae	6.2	20 4	62	21 0	335	0 57
21	118 B Ophiuchi	6.2	16 35	120	18 1	282	1 26



Apparent Paths of Mercury, Venus and Neptune
Among the Stars During 1911.



APPARENT PATHS OF MARS, JUPITER SATURN AND URANUS AMONG THE STARS DURING 1911.

THE COMETS.

Five periodic comets are due at perihelion this year and Halley's Metcalf's and Faye' scomets of the past year are not yet out of sight.

1. *Brook*'s 1889 V is due at perihelion January 8. It was in best position for observation in October 1910 and was actually observed at Lick Observatory on September 28. It is not likely to be seen in 1911.

2. *Barnard*'s comet 1884 II, if the period 5.400 years is good should, be at perihelion in August, and in favorable position for observation; but it has not been seen at any of its returns since 1884 and it is doubtful whetherthe comet will now be any where near the predicted place.

3. *Encke*'s comet which comes around every three and one-third years is due again at perihelion this year in August. It will not be very favorably placed but probably will be detected during the summer or autumn.

4. *Tempel*'s first periodic comet, which was seen at its last return, in 1905 will be at perihelion again in October. It will be nearly behind the Sun at that time but may possibly be seen a month or two earlier.

5. *Brorsen*'s comet has not been seen since 1890 and so its discovery this year is doubtful. Unless the elements of its orbit have been considerably changed, however, its position will be comparatively favorable and it may be found in the early part of the winter. It should be at perihelion in December.

VARIABLE STARS

The number of variable stars whose periods have been determined has increased rapidly the last few years. It has consequently required more and more space to carry out the plan of publishing the times of maxima or minima of most of these. Rather than omit any stars from the list we have

begun to print in some cases only alternate, or even only every third, and in two cases only every tenth minimum of Algol type stars.

These have all been computed again for 1911, in the case of the Algol type stars in which the period is less than half a day and in the case of the stars not of the Algol type in which the period is less than one day, and will be published throughout the year. The computations have been subjected to a double check, and, we think, can be depended upon as being correct.

PHASES OF THE MOON.

1911 Washington Mean time.

New Moon.			First Quarter.			Full Moon			Last Quarter		
d	h	m	d	h	m	d	h	m	d	h	m
Jan. 29	16	36.4	Jan. 7	13	12.1	Jan. 14	5	17.7	Jan. 21	13	12.5
Feb. 28	7	22.8	Feb- 5	22	19.3	Feb. 12	17	29.2	Feb. 20	10	35.9
Mar. 29	19	29.5	Mar. 7	5	53.2	Mar. 14	6	50.2	Mar. 22	7	18.1
Apr. 28	5	16.7	Apr. 5	12	46.6	Apr. 12	21	28.3	Apr. 21	1	27.4
May 27	13	16.1	May 4	20	5.4	May 12	13	1.4	May 20	16	14.6
June 25	20	11.4	June 3	4	55.9	June 11	4	42.4	June 19	3	42.5
July 25	3	3.7	July 2	16	12.1	July 10	19	45.1	July 18	12	22.5
Aug. 23	11	6.9	Aug. 1	6	21.1	Aug 9	9	46.4	Aug. 16	19	2.4
Sept. 21	21	29.1	Aug. 30	23	12.4	Sept. 7	22	48.4	Sept. 15	0	42.5
Oct. 21	11	1.0	Sept. 29	17	59.7	Oct. 7	11	2.8	Oct. 14	6	37.7
Nov. 20	3	41.1	Oct. 29	13	33.2	Nov. 5	22	39.8	Nov. 12	14	11.2
Dec. 19	22	32.0	Nov. 28	8	33.6	Dec. 5	9	43.6	Dec. 12	0	37.3
			Dec. 28	1	39.2						

VARIABLE STARS.

New Elements of RV Ursae Majoris.—Mr. S Blazko, in the *Astronomische Nachrichten* 4456 gives a slight modification of the elements for the star R V Ursae Majoris previously published by him in 4258 of the same journal. He recently made a number of observations to determine, if possible, whether or not the period of this variable might be variable. He does not discover any such variability, but shows in his table that the observed maxima agree very closely with the maxima computed from the following elements.

$$\text{Max} = \text{J. D. } 2417861.434 \text{ G.M.T.} + 0^d.468058 \text{ E.}$$

This star does not appear in our list of stars whose maxima are predicted, because of the shortness of its period.

Elements of 20.1909 Persei.—In the same article as the above are given the elements for another short period variable star, which are determined from observations made in the latter part of 1909, also by Mr. Blazko. This is the star 20.1909 Persei, and its position in 1900.0, $\alpha = 3^h\ 1^m\ 48.96^s$, $\delta = +\ 52^\circ\ 48'\ 37''.4$. The elements given are.

$$\text{Max} = \text{J. D. } 2418572.297 \text{ G.M.T.} + 0^d.607078 \text{ E.}$$

The light curve of this star indicates that it belongs to the δ Cephei type. This star also has such a short period that we shall not include it in our list. However, a little computation will enable any one to find from these elements the time of any particular maximum he may desire to observe.

Note.—The times of the minima of the star Algol (β Persei) for the months of Nov., Dec., and Jan., (1911) given respectively in the Oct., Nov., and Dec., numbers of POPULAR ASTRONOMY are inaccurate. A correction of approximately $1^h\ 50^m$, to be subtracted from the times, was omitted from the computation. Since these computations are made to the nearest minute, and published only to the nearest hour, the times given are in some cases wrong by two hours and in some others by only one.

Approximate Magnitudes of Variable Stars on Dec. 1, 1910.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
χ Androm.	0	10.8	+46	27	13.2	V Tauri	4	46.2	+17	22	9.4 *i*
T Androm.		17.2	+26	26	13.4	R Orionis		53.6	+ 7	59	10.6 *i*
T Cassiop.		17.8	+55	14	11.7	R Leporis		55.0	−14	57	6.6
R Androm.		18.8	+38	1	6.4	V Orionis	5	0.8	+ 3	58	10.2
S Ceti		19.0	− 9	53	11.3*d*	T Leporis		0.6	−22	2	8.0 *i*
γCephei		31.3	+79	48	13.5*d*	R Aurigae		9.2	+53	28	12.8*d*
U Cassiop.		40.8	+47	43	<14	S Aurigae		20.5	+34	4	10.2
RW Androm.		41.9	+32	8	8.7	W Aurigae		20.1	+36	49	12.8 *i*
V Androm.		44.6	+35	6	11.4 *i*	S Orionis		24.1	− 4	46	9.8 *i*
RR Androm.		45.9	+33	50	13.9*d*	T Orionis		30.9	− 5	32	9.6
RV Cassiop.		47.1	+46	53	<13.5	S Camelop.		30.2	+68	45	9.6 *i*
W Cassiop.		49.0	+58	1	9.0 *i*	U Aurigae		35.6	+31	59	11.8*d*
Z Ceti	1	1.6	− 2	1	12.0*d*	SU Tauri		43.	+19		13.5*d*
U Androm.		9.8	+40	11	<14	Z Tauri		46.7	+15	46	<13.8
S Piscium		12.4	+ 8	24	<14	U Orionis		49.9	+20	10	9.5*d*
S Cassiop.		12.3	+72	5	13.0*d*	V Camelop.		49.4	+74	30	13.2
U Piscium		17.7	+12	21	12.1	Z Aurigae		53.6	+53	18	9.0
R Piscium		25.5	+ 2	22	13.6	X Aurigae	6	4.4	+50	15	8.7 *i*
RU Androm.		32.8	+38	10	13.3	V Aurigae		16.5	+47	45	9.8
Y Androm.		33.7	+38	50	9.2 *i*	V Monoc.		17.7	− 2	9	12.1
X Cassiop.		49.8	+58	46	10.8*d*	S Lyncis		35.9	+58	0	11.0 *i*
U Persei		53.0	+54	20	8.2	X Gemin.		40.7	+30	23	9.0
S Arietis		59.3	+12	3	13.5*d*	R Lyncis		53.0	+55	28	9.6 *i*
R Arietis	2	10.4	+24	35	12.7	V Can. Min.	7	1.5	+ 9	2	11.2*d*
W Androm.		11.2	+43	50	9.0*d*	R Gemin.		1.3	+22	52	9.0*d*
Z Cephei		12.8	+81	13	11.4*d*	RR Monoc.		12.4	+ 1	17	11.0 *i*
o Ceti		14.3	− 3	26	7.1*d*	R Urs. Maj.	10	37.6	+69	18	11.7 *i*
S Persei		15.7	+58	8	9.3	T Urs. Maj.	12	31.8	+60	2	7.9
R Ceti		20.9	− 0	38	10.6 *i*	RS Urs. Maj.		34.4	+ 7	32	9.4 *i*
RR Persei		21.7	+50	49	<13.5	S Urs. Maj.		39.6	+61	38	11.3
U Ceti		28.9	−13	35	11.0*d*	T Urs.Min.	13	32.6	+73	56	13.0*d*
RR Cephei		30.4	+80	42	9.6 *i*	R Can. Ven.		44.6	+40	2	10.0*d*
R Trianguli		31.0	+33	50	8.8 *i*	U Urs. Min.	14	15.1	+67	15	11.1*d*
T Arietis		42.8	+17	6	8.9	S Bootis		19.5	+54	16	13.0
W Persei		43.2	+56	34	8.6	R Camelop.		25.1	+84	17	11.7 *i*
U Arietis	3	5.5	+14	25	<13	S Coronae	15	17.3	+31	44	12.1 *i*
X Ceti		14.3	− 1	26	11.4 *i*	S Urs.Min.		33.4	+78	58	9.2 *i*
Y Persei		20.9	+43	50	8.5 *i*	R Coronae		44.4	+28	28	10.8 *i*
R Persei		23.7	+35	20	13.0*d*	X Coronae		45.2	+36	35	12.2*d*
T Tauri	4	16.2	+19	18	10.6	V Coronae		46.0	+39	52	11.8*d*
R Tauri		22.8	+ 9	56	11.6 *i*	Z Coronae		52.2	+29	19	12.0
W Tauri		22.2	+15	49	10.6 *i*	RR Herculis	16	1.5	+50	46	8.8
S Tauri		23.7	+ 9	44	<13.5	RU Herculis		6.0	+25	20	12.8 *i*
RX Tauri		32.8	+ 8	9	<13.5	W Coronae		11.8	+38	3	12.2*d*
X Camelop.		32.6	+74	56	12.0*d*	W Herculis		31.7	+37	32	9.0 *i*

Approximate Magnitudes of Variable Stars on Dec. 1, 1910—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
R Draconis	16	32.4	+66	58	7.5 *i*
RV Herculis		56.8	+31	22	12.8 *i*
T Draconis	17	54.8	+58	14	12.2
— Draconis		54.7	+58	14	10.7
V Draconis		56.3	+54	53	<13
T Herculis	18	5.3	+31	0	13.0
W Draconis		5.4	+65	56	12.0 *i*
X Draconis		6.8	+66	8	12.2*d*
W Lyrae		11.5	+36	38	9.4*d*
SV Herculis		22.3	+24	58	13.2
T Serpentis		23.9	+ 6	14	9.0 *i*
RY Lyrae		41.2	+34	34	12.2
RW Lyrae		51.1	+29	44	<14.
RX Lyrae		50.4	+32	42	12.6
Z Lyrae		56.0	+34	49	10.5 *i*
RT Lyrae		57.8	+37	22	13.5*d*
R Aquilae	19	1.6	+ 8	5	12.0*d*
V Lyrae		5.2	+29	30	<13
S Lyrae		9.1	+25	50	14.0
RS Lyrae		9.3	+33	15	<13
RU Lyrae		9.1	+41	8	11.7*d*
U Draconis		9.9	+67	7	9.6 *i*
W Aquilae		10.0	− 7	13	9.7 *i*
T Sagittarii		10.5	−17	9	9.6*d*
R Sagittarii		10.8	−19	29	9.3*d*
S Sagittarii		13.6	−19	12	9.4 *i*
Z Sagittarii		13.8	−21	17	9.0
TZ Cygni		13.4	+50	0	11.6
U Lyrae		16.6	+37	42	12.0*d*
T Sagittae		17.2	+17	28	9.6
TY Cygni		29.8	+28	6	13.3*d*
R Cygni		34.1	+49	58	9.4*d*
RT Cygni		40.8	+48	32	12.6*d*
TU Cygni		43.3	+48	49	11.7 *i*
X Aquilae		46.5	+ 4	13	11.6
χ Cygni		46.7	+32	40	11.2*d*
Z Cygni		58.6	+49	46	9.0
S Cygni	20	3.4	+57	42	13.6*d*
S Aquilae		7.0	+15	19	11.2*d*
RU Aquilae		8.0	+12	42	<13.6
RS Cygni		9.8	+38	28	8.2
R Delphini		10.1	+ 8	47	10.6*d*
SX Cygni		11.6	+30	46	8.0 *i*
WX Cygni		14.8	+37	8	12.2
U Cygni		16.5	+47	35	8.2*d*
Z Delphini		28.1	+17	7	13.6
ST Cygni		29.9	+54	38	13.3*d*
Y Delphini		36.9	+11	31	13.3
S Delphini		38.5	+16	44	9.0 *i*
V Cygni		38.1	+47	47	12.7

Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn
Y Aquarii	20	39.2	− 5	12	12.6 *i*
T Delphini		40.7	+16	2	13.0 *i*
V Aquarii		41.8	+ 2	4	10.0*d*
W Aquarii		41.2	− 4	47	8.6
V Delphini		43.2	+18	58	<13.8
T Aquarii		44.7	− 5	31	10.6*d*
RZ Cygni		48.5	+46	59	11.6*d*
X Delphini		50.3	+17	16	11.0 *i*
UX Cygni		50.9	+30	2	8.6 *i*
R Vulpeculae		59.9	+23	26	11.8 *i*
TW Cygni	21	1.8	+29	0	9.6
X Cephei		3.6	+82	40	<13.5
RS Aquarii		5.8	− 4	27	12.0*d*
Z Capricorni		5.0	−16	35	13.6*d*
R Equulei		8.4	+12	23	10.7*d*
T Cephei		8.2	+68	5	8.0*d*
RR Aquarii		9.8	− 3	19	12.8*d*
X Pegasi		16.3	+14	2	12.9*d*
T Capricorni		16.5	−15	35	13.3
Y Capricorni		28.9	−14	25	<14
S Cephei		36.5	+78	10	7.8
RU Cygni		37.3	+53	52	8.6
RR Pegasi		40.0	+24	33	13.6*d*
V Pegasi		56.0	+ 5	38	13.4
RT Pegasi		59.8	+34	38	10.2 *i*
T Pegasi	22	4.0	+12	3	12.7 *i*
Y Pegasi		6.8	+13	52	13.3*d*
RS Pegasi		7.4	+14	4	<13.5
RT Aquarii		17.7	−22	34	9.2
RV Pegasi		21.0	+29	58	10.8 *i*
S Lacertae		24.6	+39	48	10.0 *i*
R Lacertae		38.8	+41	51	10.0 *i*
S Aquarii		51.8	−20	53	12.8*d*
RW Pegasi		59.2	+14	46	10.6*d*
R Pegasi	23	1.6	+10	0	8.6*d*
V Cassiop.		7.4	+59	8	7.7 *i*
W Pegasi		14.8	+25	44	9.0
S Pegasi		15.5	+ 8	22	10.8
Z Androm.		28.8	+48	16	10.6
ST Androm.		33.8	+35	13	9.3
R Aquarii		38.6	−15	50	10.2*d*
Z Cassiop.		39.7	+56	2	<13.8
Z Aquarii		47.1	−16	25	8.8
RR Cassiop.		50.7	+53	8	10.6
V Ceti		52.8	− 9	31	9.7 *i*
R Cassiop.		53.3	+50	50	11.7 *i*
Z Pegasi		55.0	+25	21	9.8*d*
W Ceti		57.0	−15	14	9.7*d*
Y Cassiop.		58.2	+55	7	9.6

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Amherst, Vassar, Mt. Holyoke, Olcott, Jacobs, Hunter and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked with an * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.			λ Tauri			*U Columbæ			**V Puppis			*SS Centauri		
	d	h		d	h		d	h		d	h		d	h
Feb.	20	2	Feb.	3	18	Feb.	4	15	Feb.	1	0	Feb.	1	23
*U Cephei				7	17		10	5		5	9		6	22
Feb.	5	9		11	16		15	19		9	18		11	21
	10	9		15	14		21	10		14	3		16	20
	15	8		19	13		27	0		18	11		21	19
	20	8		23	12	*RW Monoc.				22	20		26	18
	25	8		27	11	Feb.	2	4		27	5	*δ Libræ		
*Z Persei			*RW Tauri				6	0	†X Carinæ			Feb.	4	18
Feb.	1	5	Feb.	4	23		9	19	Feb.	3	6		9	9
	7	8		10	12		13	15		8	16		14	1
	13	11		16	1		17	0					18	17
	19	13		21	13		21	6		14	2		23	8
	25	16		27	2		25	1		19	12		28	0
RY Persei			*RV Persei				28	21		24	22			
Feb.	6	16	Feb.	1	14	RX Gemin.			S Cancri			*U Coronæ		
	13	12		5	13	Feb.	13	2	Feb.	10	6	Feb.	6	19
	20	9		9	12		25	7		19	17		13	17
	27	6		13	10	**RU Monoc.			S Velorum				20	14
**RZ Cassiop.				17	9	Feb.	2	19	Feb.	5	19		27	12
Feb.	2	15		21	8		5	11		11	17	*SW Ophiuchi		
	6	5		25	7		8	4		17	16	Feb.	5	17
	9	19	RW Persei				10	20		23	14		10	15
	13	9	Feb.	13	0		13	13	**Y Leonis				15	12
	16	23		26	5		16	6	Feb.	1	13		20	9
	20	13	RS Cephei				18	22		6	14		25	7
	24	3	Feb.	10	0		21	15		11	16	*SX Ophiuchi		
	27	17		22	10		24	7		16	17	Feb.	3	23
*ST Persei			*RY Aurigae				27	0		21	19		8	2
Feb.	2	4	Feb.	3	5	**R Canis Maj.				26	20		12	5
	7	11		8	16	Feb.	1	5	**RR Velorum				16	8
	12	18		14	2		4	15	Feb.	3	10		20	11
	18	1		19	13		8	1		9	0		24	15
	23	8		25	0		11	11		14	13		28	18
	28	15	* RZ Aurigæ				14	21		20	3			
RX Cephei			Feb.	6	22		18	6		25	17	R Aræ		
Feb.	26	15		12	23		21	16	*SS Carinae			Feb.	1	20
* β Persei				18	23		25	2	Feb.	3	20		6	7
Feb.	5	1		25	0		28	12		10	11		10	17
	10	18				RY Geminorum				17	1		15	3
	16	2	51.1908 Gemin.			Feb.	7	14		23	16		19	13
	22	5	Feb.	3	4		16	21	RW Urs. Maj.				23	23
	27	23		7	4		26	4	Feb.	7	10		28	10
**RT Persei				11	5	* Y Camelop.				14	18	**U Ophiuchi		
Feb.	3	6		15	5	Feb.	5	3		22	2	Feb.	2	21
	5	19		19	5		11	18					5	9
	8	8		23	5		18	8	**Z Draconis				7	21
	10	21		27	5		24	23	Feb.	3	10		10	10
	13	10	*RW Gemin.			RR Puppis				7	11		12	22
	15	23	Feb.	5	12	Feb.	4	20		11	13		15	11
	18	13		11	5		11	7		15	15		17	23
	21	2		16	23		17	17		19	17		20	11
	23	15		22	16		24	3		23	18		23	0
	26	4		28	10					27	20		25	12
	28	17											28	1

Minima of Variable Stars of the Algol Type.—Continued.

**SZ Herculis

	d	h
Feb.	2	8
	4	19
	7	6
	9	17
	12	4
	14	15
	17	2
	19	13
	21	23
	24	10
	26	21

Z Herculis

	d	h
Feb.	3	12
	7	12
	11	11
	15	11
	19	11
	23	11
	27	11

SX Draconis

	d	h
Feb.	3	20
	9	0
	14	4
	19	9
	24	13

*RS Sagittarii

	d	h
Feb.	1	9
	6	5
	11	1
	15	21
	20	17
	25	13

*V Serpentis

	d	h
Feb.	6	23
	13	21
	20	19
	27	17

†RZ Draconis

	d	h
Feb.	3	9
	8	21
	14	10
	19	22
	25	10

** RX Herculis

	d	h
Feb.	2	19
	5	11
	8	3
	10	19
	13	11
	16	3
	18	19
	21	11
	24	3
	26	19

*SX Sagittarii

	d	h
Feb.	3	23
	8	3
	12	7
	16	11
	20	14
	24	18
	28	22

*RR Draconis

	d	h
Feb.	5	13
	11	5
	16	21
	22	13
	28	5

**U Scuti

	d	h
Feb.	2	10
	5	7
	8	4
	11	1
	13	22
	16	18
	19	15
	22	12
	25	9
	28	5

*RX Draconis

	d	h
Feb.	4	13
	8	8
	12	2
	15	21
	19	16
	23	11
	27	6

*RV Lyræ

	d	h
Feb.	2	1
	9	6
	16	11
	23	16

16.1908 Vulpec.

	d	h
Feb.	2	17
	7	4
	11	16
	16	3
	20	15
	25	2

*U Sagittae

	d	h
Feb.	6	6
	13	1
	19	19
	26	13

Z Vulpeculæ

	d	h
Feb.	5	7
	10	5
	15	3
	20	1
	24	23

SY Cygni

	d	h
Feb.	3	9
	9	10
	15	10
	21	10
	27	10

*WW Cygni

	d	h
Feb.	3	11
	10	2
	16	18
	23	9

SW Cygni

	d	h
Feb.	3	21
	8	11
	13	0
	17	14
	22	4
	26	18

VW Cygni

	d	h
Feb.	3	16
	12	3
	20	13
	28	23

*UW Cygni

	d	h
Feb.	7	21
	14	19
	21	16
	28	14

W Delphini

	d	h
Feb.	4	17
	9	12
	14	7
	19	3
	23	22
	28	17

RR Delphini

	d	h
Feb.	3	2
	7	16
	12	6
	16	21
	21	11
	26	1

RR Vulpeculae

	d	h
Feb.	2	3
	7	4
	12	5
	17	6
	22	8
	27	9

**VV Cygni

	d	h
Feb.	1	15
	6	1
	10	12
	14	22
	19	8
	23	19
	28	5

**28.1910 Cygni

	d	h
Feb.	1	11
	4	9
	7	7
	10	5
	13	2
	16	0
	18	22
	21	20
	24	17
	27	15

WZ Cygni

	d	h
Feb.	25	5

*RT Lacertae

	d	h
Feb.	1	10
	6	12
	11	14
	16	16
	21	17
	26	19

*TT Androm.

	d	h
Feb.	5	7
	10	20
	16	9
	21	21
	27	10

21.1909 Andr.

	d	h
Feb.	1	12
	5	14
	9	17
	13	20
	17	23
	22	1
	26	4

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.

	d	h
Feb.	13	23

SY Cassiop.

	d	h
Feb.	3	18
	7	20
	11	21

SY Cassiop.

	d	h
Feb.	15	23
	20	1
	24	2
	28	4

RW Cassiop.

	d	h
Feb.	8	17
	22	2

SU Cassiop.

	d	h
Feb.	2	15
	4	14

SU Cassiop.

	d	h
Feb.	6	13
	8	12
	10	10
	12	9
	14	8
	16	7

SU Cassiop.

	d	h
Feb.	18	5
	20	4
	22	3
	24	2
	26	1
	27	23

Maxima of Variable Stars of Short Period not of the Algol Type.-Con.

SV Persei			T Velorum			RZ Centauri			Y Sagittarii			VY Cygni		
	d	h		d	h		d	h		d	h		d	h
Feb.	8	23	Feb.	4	19	Feb.	26	15	Eeb.	21	6	Feb.	6	13
	20	2		9	11		27	13		27	0		14	9
RX Aurigæ				14	2		28	12	U Sagittarii				22	6
Feb.	3	6		18	17	W Virginis				d	h	VZ Cygni		
	14	21		23	9	Feb.	13	7	Feb.	1	15	Feb.	2	14
	26	12		28	0	V Centauri				8	9		7	10
SX Aurigae			W Carinæ			Feb.	1	1		15	3		12	7
Feb.	1	11	Feb.	1	2		6	13		21	21		17	4
	3	0		5	11		12	1		28	15		22	1
	4	13		14	5		17	14	β Lyræ				26	2
	6	2		18	14		23	1	Feb.	1	1	Y Lacertae		
	7	14		22	23		28	13		7	7	Feb.	1	2
	9	3		27	8	R Triang. Austr.				13	23		5	10
	10	16	S Muscæ			Feb.	3	23		20	5		9	18
	12	5	Feb.	7	11		7	8		26	21		14	2
	13	18		17	3		10	17	κ Pavonis				18	10
	15	6		26	19		14	3	Feb.	7	4		22	17
	16	9	T Crucis				17	12		16	16		27	1
	18	8	Feb.	6	9		20	21		25	8	δ Cephei		
	19	20		13	3		24	7	U Aquilæ			Feb.	1	22
	21	9		19	20		27	16	Feb.	1	13		7	6
	22	22		26	14	S Triang. Austr.				8	14		12	15
	24	11	R Crucis			Feb.	2	5		15	15		18	0
	25	23	Feb.	1	20		8	12		22	15		23	9
	27	12		7	16		14	20	U Vulpeculæ				28	18
SY Aurigae				13	12		21	4	Feb.	8	2	Z Lacertae		
Feb.	2	3		19	7		27	12		16	1	Feb.	5	20
	12	6		25	3	S Normæ				24	1		16	17
	22	9				Feb.	8	18	SU Cygni				27	14
Y Aurigae			S Crucis				18	12	Feb.	3	9	RR Lacertae		
Feb.	3	6	Feb.	1	15		28	6		7	5	Feb.	1	1
	7	3		6	7	RV Scorpii				11	1		7	11
	10	23		11	0	Feb.	1	13		14	22		13	21
	14	20		15	16		7	14		18	18		20	7
	18	17		20	9		13	16		22	14		26	17
	22	13		25	1		19	17		26	11	V Lacertae		
	26	10	RZ Centauri				25	19	η Aquilae			Feb.	5	10
RZ Geminorum			Feb.	1	7	RV Ophiuchi			Feb.	7	15		10	9
Feb.	6	1		2	5	Feb.	3	11		14	19		15	9
	11	14		3	4		7	15		22	0		20	8
	17	2		4	2		10	20	S Sagittae				25	8
	22	15		5	1		14	13	Feb.	8	19	X Lacertae		
	28	3		5	23		18	5		17	4	Feb.	4	16
RS Orionis				6	22		21	22		25	14		10	3
Feb.	6	16		7	20		25	14	X Vulpeculae				15	13
	14	6		8	19	X Sagittarii			Feb.	1	3		21	0
	21	19		9	17	Feb.	4	18		7	10		26	11
T Monoc.				10	16		11	19		13	18	SW Cassiop.		
Feb.	19	22		11	14		18	19		20	2	Feb.	1	16
W Geminorum				12	13		25	19		26	9		7	2
Feb.	8	17		13	12	Y Ophiuchi			V Vulpeculae				12	13
	16	15		14	10	Feb.	1	9	Feb.	26	12		17	23
	24	13		15	9		18	12	X Cygni				23	10
ζ Geminorum				16	7				Feb.	3	20		28	20
Feb.	10	10		17	6	W Sagittarii				20	5			
	20	14		18	4	Feb.	3	12	T Vulpeculae			RS Cassiop.		
RU Camelop.				19	3		11	3	Feb.	3	0	Feb.	2	11
Feb.	21	20		20	1		18	17		7	10		8	18
V Carinæ				21	0		26	7		11	21		15	1
Feb.	2	15		21	22	Y Sagittarii				16	7		21	8
	9	8		22	21	Feb.	3	22		20	18		27	15
	16	0		23	19		9	16		25	4			
	22	17		24	18		15	11	TX Cygni			RY Cassiop.		
				25	16				Feb.	7	3	Feb.	10	19
										21	20		20	22

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

Total Eclipse of the Moon, November 16, 1910:—At Providence, R. I., the sky cleared during the first partial phase, and remained clear during the rest of the time. The illumination in the total phase was quite strong and the details of the lunar surface were clearly visible in the telescope. The distribution of the light was irregular. As was to be expected in the case of an eclipse in which the Moon crossed the shadow not centrally but wholly in the northern half, the northern edge was very bright and the edge nearest the center of the shadow quite dark, but the progression was far from uniform. A bright segment near the northern edge was bounded internally by a narrow dark area, then came ruddy areas and a large area approximately circular completed the disk at the southern edge. A telescope with low power showed that dark areas of the lunar surface accounted for some of the shading, but that there was a distinct dark area in the southern mountainous region near Tycho. The irregularity in the distribution of the light therefore was due to actual differences in the illumination of the shadow made by rays refracted through different regions of the Earth's atmosphere.

At the Ladd Observatory, occultations were observed during partial and total phases. No bright stars were in the Moon's path, the brighter being 7.7 magnitude. Seven stars were observed, four of which are in the catalogue of the *Astronomische Gesellschaft, Berlin A*, Nos. 935, 940, 955, 960, and the other stars of about 9.5 magnitude. Three were observed at both immersion and emersion and two each at either immersion or emersion but not at both. The ten observations without exception show that the observed times were earlier than those calculated rigidly by the data in the *American Ephemeris* using the formulae of Chauvenet. The range is from 8.3 to 20.3 seconds of time, with an average of 13.4 seconds. If this discrepancy be ascribed to errors in the Moon's place, it indicates that the Moon was ahead of its calculated position by nearly 9″. Uncertainties in the apparent places of the stars used in the calculation are however appreciable sources of error, as the positions were brought forward from 1875, and the effect of errors in right ascension is multiplied twenty fold in the times of occultation.

WINSLOW UPTON.

A Favorable Opportunity for the Amateur to find Asteroids:—It seems that few amateurs have found any of the asteroids. In fact I had thought myself that this was out of his reach but succeeding so easily in finding Vesta I have thought that possibly others might like to try it, so I am giving below the ephemerides, taken from the *British Nautical Almanac* of a few that may be seen about the time POPULAR ASTRONOMY reaches its readers. I regret that I have not at hand the ephemeris for January. Accordingly I am giving the figures for a number of days preceding the date when this information may be of use so that the ephemeris for later dates can be approximately determined by interpolation. Average the daily motion and add for the number of days in advance of date given. The magnitudes are given and so one may judge whether it will be an easy or difficult task for his instrument.

It will be noted that Vesta will be about two degrees above and less than a degree to the left of α Piscium on December 31. It is a little under the eighth magnitude and should be easily detected. The R. A. of α Piscium is 1h 57m and its Dec., 2° 17′.

Ceres is not near any conspicuous star but is fairly bright and should be easily detected.

Pallas is very close to θ Aquarii (R. A. 22h 12m; Dec. — 8° 13′) on Dec. 23 and should occasion no difficulty in its location although it is nearly a tenth magnitude object.

I have at hand the ephemeris of Juno for January and it is given in full. On Dec. 23 it is very near θ Virginis (R. A. 13h 5m; Dec. —5° 4′) and though it is of the tenth magnitude should be an easy object with the aid of a telescope of 2½ or 3 inches aperture.

EPHEMERIDES OF VESTA, CERES, PALLAS AND JUNO.

	Date.	Magnitude	R. A. h m	Dec. ° ′
Vesta	Dec. 15	7.31	1 52.9	+ 2 44
	" 23	7.42	1 53	3 21
	" 31	7.53	1 54	4 6
Ceres	Dec. 7	8.03	0 50.6	+ 6 3
	" 15	8.11	0 51.7	5 12
	" 23	8.20	0 54	4 15
	" 31	8.28	0 58	3 11
Pallas	" 7	9.69	21 56.2	— 7 40
	" 15	9.74	22 3.8	7 51
	" 23	9.79	22 12	7 55
	" 31	9.84	22 20	7 52
Juno	" 23	10.10	13 4.2	— 5 12
	" 31	10.05	13 11.6	5 31
	Jan. 8	9.99	13 18	5 43
	" 16	9.92	13 23.5	5 47
	" 24	9.86	13 27	5 42
	Feb. 1	9.79	13 30	5 27

RUEL W. ROBERTS.

Edgerton, Wis.

Observation of Vesta.—Having never seen one of the asteroids I was pleased to note the positions of Vesta and Ceres given in a recent number of the *Scientific American*, and resolved to search out one of these little worlds and see it with my own eyes.

Taking my little telescope of 2⅛″ aperture on Nov. 11, I mapped all the stars in a small region where, as near as I could determine, Vesta should be. The following nights being cloudy, I was obliged to wait till Nov 24th for a second observation, when I found all the stars in their places and no new one in the field. Consulting my star atlas and plotting the path of Vesta among the stars, I noted that it would pass near α Pisces about Dec. 1st. Turning my telescope on that star, I marked the position of all the stars in the field of view and one bright star lying just outside and to the southeast. Cloudy weather prevailing, it was November 28, when another observation was made. Turning at once to α Pisces, I observed that the bright star just outside the field of view on the 24th, had now moved into the field and lay just below and within 30′ of α Pisces, and I knew then that I was gazing at Vesta. The little planet was brighter than I anticipated and shone with a steady flow of light slightly tinted with gold. I have since followed its movements with a opera glass.

In a like manner I located and obtained my first sight of Neptune several years ago. Vesta, however, is much brighter than Neptune, and as it moves more rapidly among the stars it is not so difficult to locate.

G. WHEELER.

Duluth, Minn. Dec. 9, 1910.

What kind of a Telescope shall an Amateur buy?—There is a considerable difference of opinion even among experts as to the relative advantages of refractors and reflectors. Most amateurs are quite in the dark as to the kind of an instrument to purchase. What is more serious, many deserving an instrument have none simply because they cannot afford it. I have such especially in mind in writing these words. Any average person of normal mechanical ability can construct a reflector for himself, if he cannot afford to buy one. For about $50 or a little less for material and speculum, though not counting in my labor, I have a fine reflector that accomplishes most surprising results. It seems too bad for capable amateurs to go without a good instrument when one can be provided so reasonably. I got my speculum from Mr. Mellish. He builds a whole telescope so reasonably that any one can afford to buy one complete.

Young, in his General Astronomy, page 30, gives the refractor credit for having the decided advantage over the reflector in the amount of light finally reaching the eye, 80% as against 50% for reflectors. Now it may seem presumptuous for an amateur to raise a question when so noted an authority does not agree with him, but I am lead to raise as least a question here as I have recently learned that some reliable tests have been made, which place the two types of telescopes more nearly on a par in this one particular. Now as to my own reasons. I recently spent a whole night at Smight Observatory, Beloit College, Beloit, Wis., and through the courtesy of Professor Hamilton, the astronomer in charge, had the use of their fine 9½″ Clark refractor for the whole night. I spent the time in examining carefully those objects I had already studied in my Mellish 10″, with a single purpose to see if I could find any difference in definition and illumination. Of the planets, I examined Jupiter and Saturn and felt that the reflector gave a decidedly better definition and about the same illumination though in any difference it was in favor of the reflector. On the Moon, both the definition and illumination, as well as fineness of details brought out, were about the same. Practically no choice could be made between them on this point. On the stars, the refractor was noticeably in the advantage as to definition.

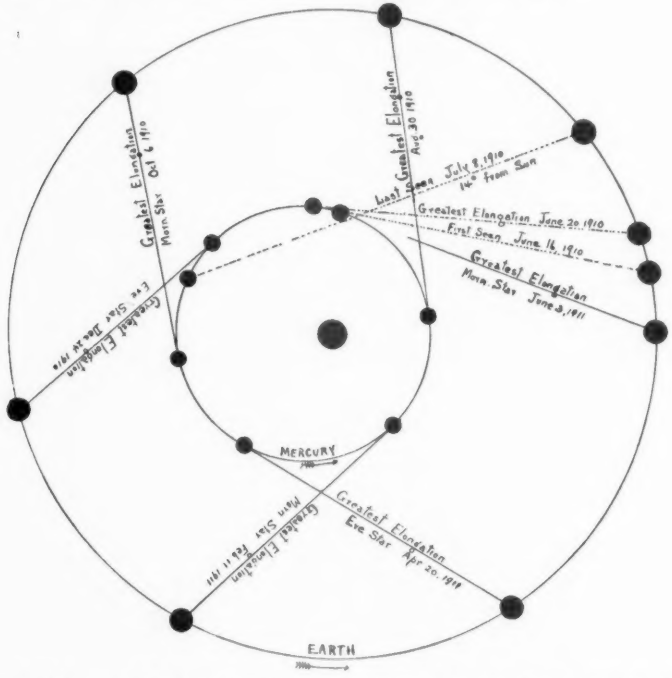
It should be remembered, however, that a reflector has to be re-silvered about once a year to keep up its efficiency. However this is not a really difficult task and costs but thirty or forty cents each time.

While it may be admitted with Young, that on the whole the refractor has somewhat the advantage and possibly one, without limitations financially, may best purchase such a refractor, still the difference between the two is so small that no amateur should go without an instrument because of financial reasons. It is certainly true that the same amount of money will buy more efficiency in a reflector than in a refractor, for it is much more handy for public work. Nor would I wish to be without a reflector. Both have served me so efficiently that I have decided to buy larger ones of both types, 5″ Brashear refractor and a 16″ Mellish reflector.

RUEL W. ROBERTS.

Edgerton, Wis.

Mercury in Puerto Rico.—We have been watching Mercury with great interest, since coming to Puerto Rico. It is seen so much more clearly and for longer time than in the north. The enclosed diagram shows our observations and calculations of its movements. The dotted lines indicate the observations and the black lines the calculations. We have a curiosity to know how nearly correct our calculations are, based on the date Aug. 30th as given in POPULAR ASTRONOMY, for the next greatest elongation.


Greatest Elongation Aug 30 1910
Last Seen July 8 1910
14° From Sun
Greatest Elongation June 20 1910
First Seen June 14 1910
Greatest Elongation Morn Star June 3 1911
Greatest Elongation Morn Star Oct 6 1910
Greatest Elongation Eve Star Dec 27 1910
MERCURY
Greatest Elongation Morn Star Feb 11 1911
Greatest Elongation Eve Star Apr 20 1911
EARTH

I think we might have seen it a week sooner than the date given June 16th as first seeing it, for it was then high up and very bright. We saw it clearly the morning of July 8th after Aldebaran had dimmed and disappeared, and at less than 14 degrees from the Sun. I think we might have seen it another morning or two, had it not been cloudy. We followed it with the telescope until sunrise, but having lost it once could not find it again. It was then nearly like the full Moon. I imagine that at its Autumnal morning appearance, being near aphelion, we shall be able to see it for 44 days, or half its period, if the mornings should be clear as they usually are here.

Alpha Centauri, seen so clearly here, but invisible in the States, is by far the most beautiful star in the telescope, not excepting Sirius, and a nebula 6 or 8 degrees west of the Southern cross, is more glorious than the Manger, though not so beautiful in the arrangement of its stars. There is a beautiful nebula about 8 degrees north east of the tip of the tail of Scorpio; but the most glorious of any nebula, that we have yet seen, lies 6 degrees southeast of

Sirius. It is not visible to the eye but is very fine in the telescope.

E. A. McDonald.

Isabela, P. R. July 14, 1910.

Ed. Note: It will be noticed that Mr. McDonald has computed the dates of elongation of Mercury, knowing only the date of greatest eastern elongation, Aug. 30, 1910, and the periods of Mercury and the Earth.

Following is a table showing Mr. McDonald's dates, the dates given in the *American Ephemeris* and the error of the former.

1910	June 20	June 19	+ 1
	Aug. 30	Aug. 30	0
	Oct. 6	Oct. 11	− 5
	Dec. 24	Dec. 24	0
1911	Feb. 11	Feb. 1	+ 10
	Apr. 20	Apr. 14	+ 6
	June 3	June 1	+ 2

GENERAL NOTES.

Dr. John A. Brashear, Pittsburgh, Pa., was awarded, by the Franklin Institute, of Philadelphia, an Elliott Cresson Medal for his work in the production and perfection of instruments for astronomical research.

Rev. Frederic Campbell, Sc. D., President of the department of astronomy of the Brooklyn Institute of Arts and Sciences, is writing the "Daily Science Talk," six weekly, syndicated by the American Press Association, This is a presentation, in popular form and often with illustration, of some point in any of the sciences, with special reference to passing events. Dr. Campbell also furnishes the daily astronomical events handled by the same corporation in its "perpetual chronology" feature in the daily press.

Mr. R. A. Sampson, F.R.S., professor of mathematics and astronomy in the University of Durham, has been named astronomer royal for Scotland and professor of practical astronomy in the University of Edinburgh, in succession to Mr. F. W. Dyson, F.R.S.

Night Letter Service.—The following communication was received from Professor E. C. Pickering with regard to a new plan for the dissemination of astronomical news from the Harvard College Observatory.

The introduction of the new Night Letter Service by the telegraph companies suggests the possibility of telegraphing astronomical positions in plain language by Night Letter, instead of the cipher telegram. The plan recommends itself more especially because of a recent rule which has increased the cost of code messages such as are now used.

By the proposed plan, position messages would be telegraphed to subscribers during the night of, or following, their receipt at this observatory, to be delivered the following morning. While the slight delay which would sometimes result may be considered, theoretically at least, an objection, the fact is that very few announcements telegraphed in the usual manner have resulted in observations on the same night. It is believed, therefore, that this difficulty would be more than offset by the advantage of messages in plain language,

requiring no translation, at a cost not exceeding the minimum rate for telegrams.

Since the distribution of orbits and ephemerides is not a matter of urgency it would be effected by mail bulletin, except in cases in which special requests for telegrams might be received.

The method of sending announcements to this observatory for distribution would be left to the discretion of the sender, at whose expense the communication would be made. Messages in code would be received as heretofore.

Your views regarding the proposed plan are solicited. Unless a majority of subscribers express an unfavorable opinion before January 1, 1911, it is proposed to introduce the plan, as outlined, upon that date.

E. C. Pickering.

Harvard College Observatory,
Cambridge, Mass. Dec. 10, 1910.

We heartily approve of the plan suggested by Professor Pickering and believe that it will result in more satisfactory service than the present one.

Researches on the Evolution of the Stellar Systems, Volume II, T. J. J. See.—This is a splendid volume of over 700 pages, magnificently gotten up and profusely illustrated with recent photographs of celestial objects. It is Dr. See's *magnum opus*, on which he says he has spent twenty-five years of study. The special title of this second volume is "The Capture Theory of Cosmical Evolution," and the author discusses a great variety of topics which are connected with the general subject. He rejects the "Nebular Hypothesis" of Laplace and substitutes for it what may be called the Spiral Hypothesis. On this hypothesis, stellar systems are formed by the meeting of vast streams of dustlike matter, which form vortices and gradually coil up, the process requiring vast ages for completion and producing in the mean time spiral nebulae. The planets and satellites are subsidiary masses formed in the spiral, which have been captured by their primaries, their orbits having been at first very elongated, but having been gradually rounded and made smaller by the secular effects of a resisting medium. The resisting medium is supposed to be composed of the dustlike material of nebular stream itself, which after long ages may be nearly all gathered into the central bodies and so exercise no further resistance.

A considerable portion of the work has already appeared in the articles by Dr. See which have been printed in the *Astronomische Nachrichten* and in POPULAR ASTRONOMY, so that an extended notice here is not necessary. We call the attention of our readers to the review of this work by Professor Eric Doolittle, published in this number.

Hagen's Atlas Stellarum Variabilium.—Some of our readers may be interested in the following communication forwarded to us by Professor Pickering, Director of Harvard College Observatory.

"I beg to inform you that I have decided to sell a limited number of Hagen's "Atlas Stellarum Variabilium," in six series, but without the cloth covers, at 100 mark per copy.

FELIX L. DAMES.

Steglitz, Berlin. Nov. 19, 1910.

This series of variable star charts is the finest extant and is practically indispensable to any one wishing to take up an extensive series of observations of variable stars. We recommend it highly to any of our readers interested in that line of work.